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## XVI.

# ON THE YOUNG STAGES OF SOME OSSEOUS FISHES.

By Alexander Agassiz.

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## Part III.*

Many interesting points of relationship between the embryos of osseous Fishes and their fossil representatives have been traced by comparing the structure of the tail of the fish embryo as it passes from the leptocardial stage through the various stages of heterocercality to a so-called homocercal stage. This relationship, as has been pointed out, is very marked, and has led to some important generalizations. The comparison of the pectorals or of the dorsal and anal fins does not, however, lead to such interesting results. It is true that as far as the pectoral fins are concerned, their resemblance in the early stages of the bony fish embryo to the crossopterygian type of pectorals is very striking, but, owing to our imperfect knowledge of the structure of the pectorals of the ancient Fishes, this comparison is at present less complete than that between the tails of the older fossil Fishes and the tails of the embryos of the modern osseous Fishes.

With regard to the comparison of the median fins of the osseous Fishes of to-day with the median fins of Fishes of earlier periods, we do not come to any satisfactory results. If we take, for instance, the change undergone by the embryos of osseous Fishes, we find invariably in the youngest stages a continuous embryonic fold, extending from the head along the dorsal side to the extremity of the tail and around the lower side to the yolk bag. At a later period, when they carry embryonic rays, these embryonic median fins resemble somewhat the fins of some of the earlier Ganoids in which the fin rays are very numerous, as, for instance, the Platygnathus of the Old Red. These characters are represented in the Ganoids of to-day both in Ceratodus and Protopterus; indeed even the Blennies, Eels, Murenidæ, and Ophididæ of to-day may be regarded as types of these embryonic stages, of which Phaneropterus with its confluent dorsal and caudal is a representative among the older fossils. But in the one case the fin rays are the permanent rays, while in the other the [embryonic] fin rays disappear with the appearance of the permanent osseous fin rays, as I have shown in my paper on the early stages of Lepidosteus.* The same conditions are repeated also in the young stages of that genus.†

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* Part I. Proc. Amer. Acad. XIII. 1877–78, p. 117; Part II. Proc. Amer. Acad. XIV. 1878–79, p. 1.

As regards the formation of the dorsals, the posterior dorsal is the first to be differentiated; in the embryos of the osseous Fishes the anterior dorsal appearing only subsequently, and either independently or connected with the posterior one. In those fishes which have these fins separated in the adult, the dorsals are usually united in the earlier stages, but if the anterior dorsal is of a peculiar type, as, for instance, in Lumpus, Trachypterus, and Lophius, the anterior dorsal becomes separated at an early stage, sometimes even while still in the egg, from the posterior dorsal. We can therefore assume that as far as the dorsals are concerned a continuous median fin still connected with the caudal is the earliest embryonic type of fin.

The next stage of development is a type in which the caudal is well separated from the dorsal and anal embryonic fold, with a continuous single dorsal ending finally by the differentiation of the dorsal into one or more independent dorsals. The formation of abnormal types of anterior dorsal to form structures adapted to special uses, as in Lophius, is an embryonic feature, and this development of the dorsal may exist either as a separate dorsal, or the anterior rays of the single dorsal may be developed to an extraordinary degree, forming immense filaments, as in Argyreiscus, Blepharis, and many other fishes.

This anterior dorsal also may exist only in the embryonic stage, as is the case in Fierasfer and Trachypterus. The anal is usually well developed before the appearance of the ventrals, except in the cases of those genera in which the ventrals take an extraordinary development and are adapted for special uses, as in the young of some Gadoids, or those genera in which the rays of the ventrals extend into large filaments, which may be of use as tactile organs. The most characteristic of these genera are found among some of the newly discovered deep-sea Fishes dredged by the "Challenger" and by the "Blake."

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* Proc. Amer. Acad., 1878, XIII. p. 65.

† In my next paper on bony Fishes, I hope to treat of the transformation of the median fins of osseous Fishes from their embryonic stage to that of fins with permanent osseous rays.

In the Fishes living at moderate depths and in pelagic Fishes the pectorals or ventrals may be developed into organs of flight, as we find it to be the case in the young of Onus, which certainly mimics to an extraordinary degree in its embryonic stages the Flying-Fishes. The specialized ventrals of the embryonic stages of Lophius and Onus may represent the huge ventral appendages, articulated fins, which exist in Pterichthys and other Devonian Fishes. The absence of ventrals or the presence of small ventrals and the existence of a large anal fin, still more or less united with the caudal and dorsal fin, may thus be regarded as embryonic characters. The differentiation of the anal is the next stage of development, and well-developed, isolated anals and ventrals are generally found to occur with well-developed and isolated dorsals. The existence of abnormally developed ventrals, as in young Gadoids, may also be considered as an embryonic character.

As far as the oldest fishes are concerned, we find in them the same dorsals and anals isolated from the heterocercal tail fin, just as they exist in many of the Fishes of the present day, and there is nothing to show that in the earliest known fossil Fishes the development of the median fins did not take place much in the same manner as it takes place to-day in the young of Lepidosteus.

There is something in the general structure of the youngest embryos of Lumpus which recalls to us the Cephalaspidæ. The position of the mouth in all young bony Fishes is characteristic of the earliest Fishes; they have in common also a cartilaginous skeleton, heterocercal tails, and a rudimentary dorsal and anal, with prominent pectorals, as in some of the fossil genera. With the Dipteridæ, although we have median fins broken up into several distinct fins and a heterocercal tail, yet these fins all belong to the embryonic posterior dorsal and anal. In the next prominent group, the Acanthodida, the heterocercal tail continues and is found to exist with single anal and dorsals, and small ventrals with well-developed pectorals. While in the Palæoniscidæ, the Dapedidæ and Pycnodonts, we find the representatives of embryonic types in which the tail becomes much less heterocercal, the anals and dorsals are each one long continuous fin with numerous rays, recalling the embryonic stages of Poronotus figured in this memoir. When, however, we reach the Jurassic, Cretaceous, and Tertiary, we come upon types more closely allied to the older stages of our bony Fishes, embryos in which an anterior dorsal is found, of which the anterior part is more or less developed, as in *Platax semiophorus* and the like, having also heterocercal tails. We also meet in these later formations genera in which the fin rays of the ventrals are still excessively developed, as in embryo Gadoids, and finally find the Fishes of the youngest formations agreeing more closely than any of their predecessors with the adult forms found in the seas of the present day.

The number of scattered papers in which various young stages of osseous Fishes are described is large, but, with the exception of the memoirs of Sundevall, of Lütken, and of an interesting chapter on Young Fishes by Günther in his Introduction to the Study of Fishes, these papers are usually limited to a single stage of development. As the present communication is mainly devoted to the study of young stages which have not as yet been described, I have quoted only those papers which had special reference to the genera here studied. I propose to incorporate the bibliography covering this subject with that of the Embryology of Fishes now in preparation for the "Selections from Embryological Monographs" to be published in vol. ix. of the Memoirs of the Museum of Comparative Zoölogy.

### LABRAX LINEATUS. *Bl. & Sch.* (*Roccus,* Gill).

(Plate I. Plate II. figs. 3, 4.)

In very young striped Bass, measuring about $3.5^{mm}$ in length (Plate I. fig. 1), the eye is of a bright blue color, with an emerald green band above the pupil. This, with the prominent silvery swimming bladder and the long line of large chromatophores extending from the vent along the base of the embryonic anal fin nearly to the extremity of the body, renders it easy to recognize the young stages of the Bass. All the stages here figured were collected on the surface with the townet. The eggs I have not found.

In the next stage (Plate I. fig. 2) the head has become proportionally larger, the mouth is placed more anteriorly, and the embryonic caudal rays are also more prominent. The muscular bands, the brain as well as the stomach, are colored a light yellowish-brown.

In the next stage (Plate I. fig. 3) the head is comparatively still larger, the body has become stouter, and the embryonic caudal is better separated from the dorsal and anal fin folds. The jaws are larger, the lower jaw projecting well beyond the upper one. In the next stage (Plate I. fig. 4), the permanent caudal is forming, and the original muscular bands around the body are more distinct than in the previous stage, otherwise the young fish does not differ materially from the stage of Plate I. fig. 3. In the next stage (Plate I. fig. 5) the caudal is almost terminal, and the posterior dorsal as well as the anal are indicated by the rudimentary permanent rays along the dorsal and anal lines.

In Plate II. fig. 3, the young Bass has a symmetrical rectangular caudal, well-developed pectoral and ventral fins, with anal and posterior dorsal completely separated from the caudal, the permanent rays large. The anterior dorsal is low, and still united with the posterior dorsal; the line of pigment spots extending along the ventral side is the only prominent one. A young Bass in the stage of Plate II. fig. 4, shows a forked caudal comparatively larger than in the adult, while the outline of the dorsal and anal is lobed, and the anterior dorsal distinct from the posterior one, and fully as high. The head has also become more elongated, and the little Bass assumes somewhat the coloring of the adult. In addition to the original ventral line of pigment spots, two prominent stripes of elongated black spots extend along the lateral line, and a less distinct line runs along the base of the dorsals. The line at the base of the dorsals is sometimes present in much younger specimens (Plate I. fig. 3 *a*) not older than those of Plate I. fig. 3. In a younger stage than Plate I. fig. 3 *a*, this dorsal line was interrupted, consisting of three patches along the base of the dorsals. The pigment spot which appeared at the base of the caudal rays as early as in stage Plate I. fig. 2, now extends as a short line across the base of the permanent rays.

### Temnodon saltator, *Lin.* (*Ponatomus saltatrix*, Gill).

(Plate II. fig. 5.)

Of the Carangidæ I have only found on the surface one small Blue fish (Plate II. fig. 5) measuring $9^{mm}$ in length. The tail fin was but slightly forked; the anterior dorsal rudimentary, but the base of the permanent fin rays already present; permanent fin rays existing in the posterior dorsal as well as the anal; large pectorals, rudimentary ventrals. Teeth of upper and lower jaw already quite prominent; body elongate, angular. Prominent line of black pigment spots extending from the top of the head to the end of posterior dorsal along upper side of stomach and base of anal and caudal. Eye bright blue, bluish silvery body with a few faint pigment cells uniformly scattered over the flanks. The Carangidæ with rudimentary ventrals and no anterior dorsals are evidently genera representing the embryonic stages of this family.

## STROMATEUS TRIACANTHUS, *Peck* (*Poronotus triacanthus*, Gill).

(Plate VI.)

The more advanced stages of the Butterfish (from 10–20$^{mm}$ in length and larger) are frequently found within the tentacles of our common Dactylometra. The younger stages were, however, all fished up from the surface with the hand-net.

The youngest stage of Poronotus observed measured 7$^{mm}$ in length (Plate VI. fig. 1). The body in this stage is comparatively stout, the head large. The caudal is already developing, though the embryonic lobe is still present; the urostyle is quite large. The dorsal and anal embryonic fins are narrow. The pectoral is large, rounded, transparent, the permanent rays well developed. The eye is large, and has the peculiar greenish-brown metallic lustre of the adult; this makes it comparatively easy to recognize the embryo Butterfish in the early stages.

There is a line of large chromatophores along the base of the anal, extending from the vent along the ventral line to the operculum, a few large pigment cells (four to five) on the digestive cavity, and a large patch over the swimming bladder. There are four comparatively small pigment cells along the lateral line, three to four along the dorsal line behind the head, and eight to ten irregular pigment spots on the head above the eye, with three or four small pigment cells in advance of the eye and on the jaws. In the following stage (Plate VI. fig. 2) the anterior part of the body and the head have a light brownish tint, the tail fin is nearly symmetrical, it has permanent fin rays with three articulations, the body is somewhat more elongated, there are the first traces of the permanent dorsal and anal fin rays along the dorsal and ventral lines. The general distribution of the pigment spots is very similar to that of the previous stages; the cells are, however, somewhat more dendritic. In the following stage figured (Plate VI. fig. 3) the chromatophores have greatly increased in number and size, especially on the upper part of the head and along the flanks of the anterior part of the body. There is now a double line of dendritic cells extending along the base of the anal and of the dorsal, and a few small cells at the base of the caudal rays. The dorsal and anal fins are separated from the caudal by a deep cut, but the caudal embryonic fin fold is still quite broad, and extends well beyond the base of the tail.

In the next stage (Plate VI. fig. 4) the young Poronotus has assumed, though faintly, the general coloring of the adult. The whole body is slightly tinted with yellowish brown, the head and anterior part of the body being darkest, with patches of carmine between the eye and base of the brain. The upper part of the head, the anterior part of the dorsal line, and the flanks of the body are well covered with large dendritic chromatophores closely packed together. Large and more distinct cells cover the sides of the body behind the digestive cavity. A row of longitudinal bars of pigment extends along the whole base of the dorsal, while delicate dendritic cells extend along the base of the anal and at the base of the caudal rays. The caudal in this stage has become slightly forked, the dorsal and anal are high, still better separated from the caudal than in the previous stage. The mucous pores of the head are already quite numerous along the operculum and near the nostrils. When the young Butterfish has reached a length of $16^{mm}$ (Plate VI. fig. 5) the body has become much broader, the mucous pores of the head have greatly increased from the previous stage figured, the chromatophores of the anterior part of the body, above the head, along the dorsal region, and over the stomach have become very numerous, they extend over the anterior part of the dorsal, with a double line of rectangular spots along the base to the extremity, and a similar double line extends along the base of the ventral. The dorsal and anal, as well as the caudal, have assumed very nearly the outline they have in the adult; the permanent rays are well articulated in the median fins.

### ATHERINICHTHYS NOTATA, *Günth.* (*Chirostoma,* Gill).

(Plates X., XI.)

The youngest specimens of Atherina (Plate X. fig. 1) are striking for their coloring, a light yellow tint extending over the whole embryo. The young Atherina is readily recognized from its light-blue eye, with greenish-emerald band above the pupil, and large otoliths, the patches of large chromatophores along the upper and lower side of the stomach, and three lines of rectangular pigment cells extending, the one along the whole base of the embryonic anal, the second along the lateral line, the third along the base of the posterior extremity of the embryonic dorsal. The next stage figured (Plate X. fig. 2) is characterized by its proportionally larger head, by the presence of a large dendritic pigment cell over the base of the brain, with five rounded spots in front of it over the principal lobe of the brain, and similar spots behind extending into the dorsal line of pigment spots, which in this stage runs along the whole base of the embryonic dorsal, and forms a line fully as marked as the other two already existing in the younger stage. In this stage the yellow coloring of the body is more intense along the upper part of the head, over the stomach, and along the dorsal line, than in the younger stages. The large dendritic pigment cells on the top of the head are sometimes found in specimens quite as young as Plate X. fig. 1. In the stage of Plate X. fig. 2, the caudal fin is forming.

In the next stage figured (Plate X. fig. 4) the head has become somewhat lengthened, the caudal fin more terminal, the embryonic caudal lobe quite rounded; the yellow coloring of the body and head is more marked, and has assumed at the same time a somewhat greenish tinge. The embryonic dorsal and anal are slightly lobed; the first trace of the base of the permanent dorsal and anal rays can be seen along the dorsal and ventral lines. There are very rudimentary ventrals as slight projections, one on each side of the anterior part of the embryonic anal. The diagonal muscular bands are well marked. The three lines of pigment cells are more prominent than they were in the preceding stage.

In a somewhat older stage (Plate XI. fig. 5) the head is proportionally more elongate than in younger stages. The caudal fin is nearly symmetrical, but with a slight trace of the embryonic caudal lobe; the dorsal and anal are well separated from the caudal; their permanent fin rays have commenced to form, though not as well advanced as those of the caudal.

In the next stage figured, when the young Atherina has attained a length of about $16^{mm}$ (Plate XI. fig. 6), the general outline of the head and body is much that of the adult; but the tail fin is still rounded; there is but a trace of the anterior dorsal; the dorsal and anal are still quite low, though completely separated from the caudal; the anterior part of the anal embryonic fin, in which no permanent rays are formed, has not entirely disappeared; the ventrals have greatly increased in length since the stage of Plate XI. fig. 5. The caudal rays are edged with rows of narrow pigment cells, while in the preceding younger stage the pigment spots of the caudal were limited to the base of the rays (Plate X. figs. 3, 4), or there are but a few irregularly scattered along the fin rays (Plate X. fig. 5). There is a marked line of pigment cells along the base of the dorsal and anal; in the anal an additional line of pigment spots runs near the outer edge of the fins. The general coloring of this stage approaches quite nearly that of the adult, though the body and the lateral line do not have quite as silvery a lustre as in the older stages.

In the oldest Atherina here figured the snout has become quite pointed (Plate XI. fig. 7). The anterior dorsal has made its appearance, the caudal is forked, the dorsal and anal are high, having much the shape they have in the adult, the pectorals are quite pointed. The permanent rays of all the fins are now edged with narrow pigment cells. The pigment spots of the lateral line consist of three or four irregular lines of minute dendritic chromatophores, while the dorsal line is made up of two irregular lines of large spots extending from the snout to the base of the tail. The ventral line extends only from a point slightly in advance of the base of the anal to the caudal fin; it also consists, like the dorsal line, of two irregular lines of elongated pigment spots. In this stage the young Atherina has fairly assumed the principal characteristic features of the adult.

## BATRACHUS TAU, *Lin.*

(Plate XVI. fig. 1.)

Dr. Storer has given a figure of a young Batrachus (Mem. Amer. Acad. v., Plate XIX.) measuring about $2^{mm}$ in length. It differs but slightly from the large specimens, the more rounded outline of the head, as seen from above, and the greater elongation of the head characterising this younger stage.

A young specimen (Plate XVI. fig. 1), measuring only $8^{mm}$ in length, was slender, the pectorals fully developed; the openings in the mucous membrane of the head were well developed, the ventrals small; the dorsal and anal fins were still connected with the embryonic caudal, the separation between the anal and caudal being but little marked. The tail fin was still in an embryonic stage, with a well-marked trace of the ganoid lobe. The whole fish was dotted with small pigment spots, with a few larger cells scattered irregularly over the surface; the pectorals were similarly covered. The general tint of body and fin was gray, with blackish and yellowish pigment cells.

### LOPHIUS PISCATORIUS, *Lin.*

(Plate XVI. figs. 2–5; Plates XVII., XVIII.)

The eggs of Lophius are laid embedded in an immense ribbon-shaped mucous band, from two to three feet broad and from twenty-five to thirty feet long. This gelatinous mass is often found floating on the surface of the sea during the last part of August. It looks at a short distance like an immense crape. The mucous mass is of a light violet gray color, and the dark black pigment spots of the young Lophius, still in the egg, give to the mass a somewhat blackish appearance. The eggs are laid in a single irregular layer through the mass, usually well separated by the mucus in which they float (Plate XVI. fig. 2).

When just hatched (Plate XVI. fig. 4) it would be difficult to recognize the young as the embryo of Lophius. It has but a single first dorsal element, a narrow short spathula-shaped ventral, and a small circular pectoral. These characters, with its transversally flattened body and head, seem in this stage to have no relation to the vertically flattened adult Lophius. The embryo in this stage, as well as while still in the egg (Plate XVI. fig. 3), and until it is far more advanced (Plate XVI. fig. 5, Plate XVII. fig. 7), is remarkable for the great width of the embryonic fin fold along the dorsal and ventral lines, the very straight notochord, and the three or four prominent patches of intense black pigment cells placed at equal distances along the lower, upper, and terminal parts of the chord. The tail pigment spots extend on both sides of the notochord, and form the largest of the three patches. This is the case from the earliest stages, until the body of the young Lophius is completely covered by pigment cells, as in the oldest stage here figured (Plate XVIII. fig. 2). I have already on a former occasion figured some of the changes which the tail undergoes as the embryo passes from the stage of Plate XVII. fig. 3, to the oldest stage of the young Lophius (Plate XVIII. fig. 2).

The principal changes of form of the body of the young Lophius consist in the gradual flattening of the head, and at the same time the increase in the proportion of the head as compared to the rest of the body, — a feature in which Lophius and the Cottoids differ somewhat from the post-embryonic changes of other osseous Fishes, where the head loses in later stages the comparatively huge size which characterizes nearly all the younger stages of bony Fishes soon after they leave the egg.

The yolk bag of the young Lophius when just hatched is comparatively small (Plate XVI. fig. 4), being almost entirely absorbed while still in the egg, and it soon disappears entirely (Plate XVI. fig. 5). In a somewhat younger stage, taken out of the egg (Plate XVI. fig. 3), it is quite globular, and the first trace of the pectorals and of the ventrals as a mere fold of the embryonic fin fold, which extends over the yolk bag, is still well shown.

In these earlier stages (Plate XVI. fig. 3, and Plate XVI. fig. 1) the embryonic fin folds are covered with minute round black pigment spots. It is only in much more advanced stages (Plate XVIII. fig. 1) that we begin to find traces of the ordinary dendritic pigment spots which eventually cover the dorsal, anal, and caudal fins (Plate XVIII. fig. 2).

The young a few days after hatching (Plate XVI. fig. 5) differ from the preceding stage mainly in the greater elongation of the head, the disappearance of the yolk bag, the comparatively larger pectorals, and in the position of the eye, which is somewhat higher. In the next stages (Plate XVII. figs. 1–3) the head has become still more elongated, the lower jaw projects well beyond the upper jaw, the branchiæ are well developed, the eye has assumed a still higher position in the head, the pectorals have greatly increased in size, the single anterior dorsal element is more than double what it was in the size figured before, and the ventrals have become greatly lengthened, showing a trace of the second ray at the base of the larger ones. The alimentary canal is well circumscribed, and the pigment spots over the remainder of the yolk bag, the top of the brain, and the base of the chorda are of an intense black, with a slight tinge of yellow over the alimentary canal.

The outline of the body has somewhat lengthened, the embryonic dorsal and ventral fins remain of great width, showing as yet no trace of separation of an anal or dorsal or caudal fin, beyond the presence of embryonic fin rays in the large caudal pigment spot (Plate XVII. fig. 3), already present in younger stages.

In somewhat older stages the original dorsal ray shows a trace of a second ray behind its base (Plate XVII. fig. 4), which in a still older stage attains half the length of the original ray (Plate XVII. fig. 5.). The second ray of the pectorals of this same stage (Plate

XVII. fig. 4) has also greatly increased in length from that of Plate XVII. fig. 3, the original pectoral ray at the same time having become so bent that the extremity forms an obtuse angle with the base. The separation of the anterior from the posterior dorsal takes place at a very early stage, already within the egg (Plate XVI. fig. 3), the first ray of the anterior dorsal pushes its way through the embryonic dorsal fold in a slight depression formed above the head, and thus forms the separation of the anterior part of the dorsal embryonic fold from the posterior. In a view from above of the young Lophius within the egg, the derivation of the pectorals and of the ventrals from the embryonic fin fold which covers the yolk bag is well seen. The paired fins are formed in the same manner on the yolk fold. They belong to the original embryonic fin fold, which splits, so as to cover the yolk bag.

Plate XVII. fig. 6, represents the embryo Lophius in a somewhat older stage than when the dorsals and ventrals are in stage figured on Plate XVI. figs. 4, 5. The dorsal and ventral embryonic folds are somewhat more opaque, both from the greater number of pigment spots, which, however, are of lighter tint than in younger stages, and from the additional number of embryonic fin rays. These are now very closely placed together on the dorsal side; they are somewhat less numerous and more distant on the ventral side. This stage is remarkable also for the great size of the lobed fleshy pectorals, with rows of light gray dendritic pigment cells along the line of the embryonic rays. There is a rudiment of a third dorsal ray, and the second ray of the ventral is more than half as long as the original ray. Teeth are well developed on the lower jaw. In the next stage figured (Plate XVIII. fig. 1) the principal differences consist in the increased length of the anterior dorsal rays (there are three rays now, and the rudiment of a fourth), the increase in length of the two ventral rays and the appearance of a rudiment of a third ray. Muscular bands are now more distinct along the body than in the younger stages; the three principal pigment spots have become broken up into smaller dendritic pigment cells, and we have the first trace of the formation of a caudal fin in the widening of the body immediately below the anterior part of the caudal pigment spots. The fleshy pectoral has become still larger than in the last stage figured; the dendritic stellate chromatophores of the head and of the ventral region of the pectoral side of the body are more numerous; the head has greatly increased in size, it is colored light yellow; the muscular bands and the tissues below the patches of the chromatophores along the body line are of the same color. The broad flat fin rays, dorsal and ventral, are of a grayish tint; the eye is blue. In the oldest of the young Lophius which I have had occasion to examine (Plate XVIII. figs. 2, 3) the changes from the preceding stage are very great. Although the body is still laterally compressed, the head, which has greatly increased in size, as well as the body anterior to the anal opening have become somewhat flattened vertically, the first trace of the great flattening so characteristic of the genus. The anterior part of the head projects proportionally far in advance of the orbits, the head sloping less from the base of the anterior dorsal ray than in preceding stages. The pectorals have now become enormous, they extend across the whole width of the body of the young Lophius, they are lobed at the edge, the rays articulated, well marked, and edged with rows of elongated dark pigment spots. The tail fin is well formed, though it still retains its ganoid shape, and the posterior dorsal and anal, though well formed, are still connected by a distinct remnant of the dorsal and ventral embryonic fin fold with the caudal fin. The anterior dorsal now has five rays, with a rudimentary one anterior to the first formed ray. These rays are connected at the base by a fin fold at a much higher point than in younger stages; they extend far beyond the fold; the extremities curve down about a quarter of the length of the ray. The increase in length of the ventral rays has been still more remarkable. The original ventral ray is now nearly twice as long as the body of the fish, and the second ray extends fully as far as the extremity of the caudal fin. There are two shorter exterior rays and one interior ray; they are joined by a membrane extending nearly to the base of the caudal, so that when expanded and seen from above the ventrals appear like regular wings. Their great size and the shape of the peculiar pectorals is well seen in the figure from above (Plate XVIII. fig. 3). The general color of the body of the largest specimens here figured is of a very light, dirty violet tint, of an olive green along the dorsal line; the body and head are covered by darker violet gray pigment spots. The pigment spots of the ventrals are of an intense black, as well as a few of the spots along the extremity of the urostyle. The pigment cells, of a violet gray, are especially numerous along the line of the pectoral rays, with a row of darker cells at their base (fig. 10). The dorsal, anal, and caudal fins are still very transparent, with a delicate tinge of violet. The young Lophius is very active during its embryonic stages, in striking contrast to the sluggish habits of the adult. The adult is comparatively a deep-water fish. I have dredged it in the "Blake" as low down as 320 fathoms off Newport. The females undoubtedly come to shallower waters to spawn, as they are not an uncommon fish during July and August, being frequently found left by the tide on the flat where they come to spawn.

The young in the stages here figured are pelagic Fishes; they were all collected, during July, August, and September, on the surface both at Newport and in Massachusetts Bay. The young hatched from the egg were only raised as far as the stage represented in Plate XVI. fig. 4. The young fishes frequently assume, when at rest, an inclined position, much as the young Garpike, and do not float horizontally as other bony Fishes do. See the figure in my former paper on the development of the tail in Plate II. Vol. XIII. Proc. Amer. Acad. 1877–78.

Günther* has figured (on p. 471, Introduction to the Study of Fishes) a young Lophius measuring over 70$^{\mathrm{mm}}$ in length, in which there are three long anterior dorsal filaments. The older of the young stages I figure resemble somewhat Melanocetus. The general resemblance of the more advanced stages of Lophius (Plate XVII. figs. 3, 6, Plate XVIII. fig. 1) to the Ophididæ and Macrouridæ is very striking.

Somewhat similar to the egg ribbons of Lophius are the masses of eggs laid by Fierasfer described by Risso and Cavolini, and also well figured by Emery,† who has followed the development of the young and given excellent figures of different stages; see Emery, Plate I. fig. 2, Plate II. figs. 5–7. They assume also, as do the young of Lophius, a peculiar slanting attitude characteristic of certain stages of growth. It is most interesting that such distant types as Lophius and Fierasfer should in their embryonic stages show such close resemblances. Compare the figures of this paper and figs. 5 and 6 of Plate II. of Dr. Emery's Memoir. It is not extraordinary that these forms should have been described under the different generic names of Vexillifer, Helminthostoma, and Porobranchus. The temporary dorsal appendage which is so prominent in the young Fierasfer (Emery, Plate I. fig. 2) is developed much in the same way as the permanent dorsal appendages of Lophius, which are eventually changed to the appendages used for fishing by the adult. What part this temporary dorsal appendage plays in Fierasfer is not known, but Emery supposes it to have the same function as in Lophius.

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* See also Ann. and Mag. of Nat. Hist. 1861, vii. (3), p. 190.

† Fauna u. Flora d. Golfes v. Neapel. II. Monographie. Fierasfer, v. Dr., Carlo Emery, 1880.

### COTTUS GRŒNLANDICUS, *C. & V.*

(Plate III., Plate II. figs. 1, 2.)

The eggs of this species (Plate III. fig. 1) are found floating on the surface; they are readily recognized from the number of small oil globules (from 10–12) which the yolk contains. Other Cottoids lay their eggs in bunches attached to the bottom, or singly between stones in shallow water. The young immediately on hatching (Plate III. fig. 2) are characterized by the great width of the anterior part of the body, the breadth of the embryonic dorsal fin toward the head, and the great size of the fleshy pectorals. Viewed from above, when slightly older (Plate III. fig. 3), the pectorals are seen to project far beyond the general outline as thick fleshy flaps; their formation as a fold of the primitive lateral embryonic fold is well shown in the stages within the egg (Plate III. fig. 1*a* 1*c*); in the last stage (Plate III. fig. 1*c*) they appear to stand independently of the body upon the yolk mass. In the stages of Plate III. figs. 4, 5, the rapid increase in the size of the head and of the pectorals can be traced. In the stage of Plate III. fig. 4, the permanent pectoral fin rays are commencing to form, and in Plate III. fig. 5, what we may call the crossopterygian stage of the pectorals is very striking.

The development of the anterior part of the body goes on, as in Lumpus, much more rapidly than that of the posterior, and at a stage (Plate II. fig. 1) where the Cottoid characters of the head and pectorals are already very striking, the embryonic dorsal and anal folds are still united with the caudal fold, and the tail only shows, as yet, a rudimentary caudal fin and the beginning of the ventrals.

In the next stage (Plate II. fig. 2) the spiny processes of the operculum and head of the young Cottus are well developed, and the pectorals fins have all the appearance of that of older specimens; the ventrals are well advanced, the dorsals and anals are separated from the caudal fin, the permanent fin rays are quite prominent, and the anterior dorsal exists as a low fin.

The general coloring of this stage of the young Cottus is of a dirty yellowish brown, with patches of darker pigment cells and black spots along the base of the anal fin, of the pectorals, and of the upper part of the stomach and head. In the youngest stages (Plate III. figs. 2, 3) there are two large patches of yellowish brown along the dorsal embryonic fin, four along the ventral, and the outer edge of the pectorals is colored in the same manner. In the subsequent stages (Plate III. fig. 4, and Plate II. fig. 1) the young have the general coloring of the older stages. This seems characteristic of other Cottoids, as in a young *Hemitripterus acadianus* corresponding to Plate III. fig. 4; the brilliant red coloring so characteristic of the adult is the prevailing tint of the pigment spots of that early stage.

## CYCLOPTERUS LUMPUS, *Lin.*

(Plates IV. V.)

In the youngest stage of this species I have had occasion to examine (Plate IV. fig. 1), measuring $4^{mm}$, the caudal fin was already partly separated from the dorsal and ventral embryonic fin. The spiny rays were also indistinctly indicated in those fins. The pectorals were large, the rays gradually diminishing in length towards their junction with the sucking disk (the modified ventrals on the abdominal side). The anterior dorsal is formed evidently, as in Lophius, at an early stage, and separates, as in that genus, the anterior and posterior parts of the embryonic dorsal fin. The younger stages of Lumpus (Plate IV. figs. 1–4) are noted for the great length of the urostyle. The head of the younger stages is remarkable for its great length and breadth (Plate IV. figs. 1–4). The great prominence of the pigment spots on the anterior part of the young fish, as far as the base of the dorsal and ventral embryonic fins, gives the young Lumpus a very striking appearance. It resembles somewhat the armored Fishes of the Old Red, and we are strongly reminded of the restorations of Coccosteus in such stages as those of Plate IV. figs. 1 and 3. With increasing age and size (Plate IV. figs. 3, 4) the young Lumpus is more uniformly covered by pigment cells, the posterior part of the body becomes less transparent, more fleshy, and it loses its ancient look, resembling more, at this stage (Plate IV. fig. 4), the young of Batrachus, which may, indeed, be said to be a permanent condition of this stage of Lumpus (with the exception of the absence of the sucking disk in Batrachus). The posterior dorsal and the ventral have become well separated from the caudal fin, which in Plate IV. fig. 4, has nearly completely lost its ganoid shape, having become almost symmetrical. The urostyle, however, is still marked by its great length. The permanent rays of the median fins are well advanced (Plate IV. fig. 4); the paired fins have not changed materially since the last stage (Plate IV. fig. 3). There is great diversity in the coloring of the young of Lumpus. In the youngest stages (Plate IV. figs. 1–3) the head, in a line drawn nearly vertically below the base of the anterior dorsal, is of a light chocolate brown, with a darker brown band extending from the nostrils above the eye to the base of the anterior dorsal. A light blue band extends from the rear of the eye to the top of the operculum, and in front of the eye to the nostrils. A blue spot of similar tint is found at the posterior base of the dorsal and at the base of the caudal extremity of the posterior dorsal. The rest of the body is straw colored. The young of stage represented in Plate IV. fig. 4, were usually of a bright olive green, darkest towards the dorsal side, with the same blue band extending towards the operculum from the rear of the orbit, with one or two round blue spots above the level of the pectorals along the lateral line. Other specimens were of a bluish neutral slate tint, uniformly spotted with darker pigment cells, with the same blue band between the eyes, above the nostrils, and behind the eyes. This was also the coloring of the oldest of the young specimens caught (Plate V. figs. 1, 3), resembling in general the bluish coloring of the adult, only of a darker tint.

The intermediate stages varied greatly in coloring; some were of a yellowish brown spotted with chocolate-colored patches, with light greenish bands behind the eyes, and five roundish spots of the same color along the lateral line, and a similar number of larger spots along the base of the posterior dorsal, extending, in some specimens, along the median dorsal line of the body to the colored band extending between the eyes. Other stages, with a similar arrangement of elliptical spots of a bluish tint along the dorsal and lateral lines, were of a reddish brown color with pigment patches of a darker greenish or of a brownish color, the abdominal region being of a lighter color.

In the stage of Plate V. figs. 1, 2, the anterior part of the body already assumes somewhat the angular outline characteristic of the adult, though these young stages are all more elongated than the adult, having also the head comparatively well separated from the posterior part of the body. The young in the stages of Plate V. figs. 1, 2, do not as yet show any traces of the prominent rows of spiny tubercles formed in the adult. These were developed to a slight extent in young Lumpus measuring 34$^{mm}$ in length (Plate V. figs. 3, 4) : a line commencing to form along the anterior slope of the anterior dorsal, a less prominent horizontal row on a level with the line of the orbits close to the eyes, a third lateral one along the body at the level of the upper extremity of the operculum. This, the most prominent of the rows, consisted of large, elliptical protuberances, through which spiny processes projected (Plate V. figs. 3 *a*, 3 *b*), and a last row of somewhat smaller tubercles along the median line of the abdomen behind the ventrals. The anterior dorsal fins of these young stages (Plate V. figs. 3, 4) resemble greatly such permanent anterior dorsals as exist in Chironectes, for instance.

In the older stages (Plate V. figs. 1–4) the anterior dorsal has become well separated from the posterior, the median fins are entirely isolated, with well-developed fin rays, and the caudal has become symmetrical. The pectorals are somewhat larger, but otherwise they and the ventral fin disks (Plate V. fig. 3 *c*) do not differ much from their condition in younger stages. The early development of the pectorals seems a marked characteristic of all embryos of osseous Fishes.

These young stages of Lumpus were all collected close to the shore; they were found living among the eel-grass at Nahant, near low-water mark. Günther has figured* the young of *Cyclopterus spinosus*. Of these stages, the youngest correspond to the oldest stage of *Cyclopterus lumpus* here figured, the oldest measuring over 45$^{mm}$ in length.

## GASTEROSTEUS ACULEATUS, *Lin.*

(Plate IX.)

The changes due to growth in Gasterosteus closely resemble those of Fundulus. The principal differences consist in the longer persistence of the embryonic tail lobe, which is still very prominent (Plate IX. fig. 1) at a stage when in Fundulus the tail has become nearly symmetrical. The notochord continues to extend into the tail as late as the stage of Plate IX. fig. 4. The chromatophores are in the shape of irregular spots during early stages; they become more and more dendritic as the young fish grow older (Plate IX. figs. 2, 3, 4). In the stage of fig. 4 they begin to assume the arrangement forming the vertical bands of the adult, and in the oldest stage here figured (Plate

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* An Introduction to the Study of Fishes (1880), p. 485.

IX. fig. 5) the general pattern is similar to that of the adult. In subsequent stages the spiny processes of the operculum are developed as well as those of the large ray of the ventrals. The ventrals make their appearance at about the time of the disappearance of the yolk bag (Plate IX. fig. 3), somewhat later than the formation of the rudimentary anterior dorsal spine (Plate IX. fig. 2). The outline of the young fish becomes more compact with age, passing gradually through the changes represented in Plate IX. figs. 1–5, from an elongated slender fish to one with a comparatively broader and stouter body.

## PELAGIC FISH EGGS.

The number of species of marine Fishes of which the eggs are pelagic is probably quite large. Scarcely a summer passes without some new egg being brought to light by the surface-fishing carried on at Newport. The eggs of the majority of our species of Flounders, those of Ctenolabrus, of Tantoga, of several species of Cottus, I know, from my own observation, to float on the surface of the water. Häckel has called attention to the pelagic eggs of Lota or some Gadoid which he had observed as early as 1866. Sars has shown the same to be the case with the eggs of the Cod. Mr. Ryder has figured the eggs of the Spanish Mackerel (Bull. U. S. Fish Com., i. Pl.) Both he and E. van Beneden, who also has observed pelagic fish eggs (Quarterly Journal Mic. Soc. 1878), have called attention to the value of these pelagic fish eggs for embryonic investigations. Mr. Ryder has also made observations of the spawning of Zeus, and suggests that many of the marine Fishes are nocturnal spawners. That this is the case with many of the Fishes I have named above seems probable from the state of segmentation in which they are found to be on the morning following the day on which they were collected. The pelagic eggs collected during the day were invariably well advanced, and the experiments for artificial fecundation which I have made with Ctenolabrus and Tautoga to obtain the very earliest stages of the development of the egg were invariably made late in the afternoon, towards dusk. I have long known the eggs of Lophius to occur floating on the surface as a gigantic mucous band, and they have also been subsequently collected by the U. S. Fish Commission. The eggs of Fierasfer are also pelagic; see Emery's monograph. I have myself also collected the eggs of the Spanish mackerel on the surface, and have observed a couple of stages of the young considerably more advanced than those figured by Mr. Ryder. The youngest of the stages I have observed correspond very closely with the stage figured by Mr. Ryder on Plate IV. fig. 16, Bull. U. S. Fish Com. It was remarkable, however, for having a lateral anal opening close to the notochord, the anal embryonic fin extending unbroken beneath it from the operculum to the extremity of the tail. The older stages are very readily distinguished from other fish embryos by the large pigment spots which are formed one above the other, and by three large patches dividing the posterior part of the body into nearly equal parts, from the extremity of the anal opening to the tail.

### CTENOLABRUS CŒRULEUS, *Dek.*

(Plates XIII. XIV. XV.)

The egg of Ctenolabrus floats on the surface immediately after being laid, and the eggs in all stages of development are fished up with the hand-net from June to the last part of August. The greater number of the eggs appear to be laid in July. The segmentation of the egg is rapid; in less than twelve hours after fecundation there are sixteen segmental spheres. In fifty hours the embryonic cap is well formed; in fifty-two hours the eyes are blocked out; and the young fish is hatched in from four and a half to five days in the stage of Plate XIII. fig. 1, measuring about $2^{mm}$ in length. The yolk bag is large, elliptical, and it (as well as the embryonic fin fold) is free from chromatic cells, which cover only the dorsal part of the body, and stop a little way short of the extremity of the notochord. On the second day after hatching (Plate XIII. fig. 2) the young Ctenolabrus is about $3^{mm}$ in length, the body is much more elongated, the head especially has lengthened, the distance between the eyes and the otoliths is nearly double, the rudimentary pectorals are better marked, and the distance of the vent from the yolk has greatly increased. The black chromatic cells have also increased in number, and are proportionally smaller than in the preceding stages. On the third day after hatching (Plate XIII. fig. 3) the young Fish presents a totally different appearance: the chromatophores characteristic of the early stages within the egg immediately after hatching have disappeared, there are left but a few large cells in the anterior part of the head, behind the pectorals along the dorsal, while there are in this and the subsequent stage (Plate XIII. fig. 4) large patches of pigment cells, and large chromatophores at the base of the anterior termination of the notochord below the level of the eyes. We find also along the body a large patch at the posterior extremity of the stomach, a second at the end of the intestine near the vent, with a smaller patch between this and the anterior one, and a third prominent patch extending across the body half way between the vent and extremity of tail, with a couple of smaller spots in front and one behind this patch. In the stage of Plate XIII. fig. 3, the opening of the mouth is still inferior, the pectorals have greatly increased in size since the preceding stage, the body has much lengthened, the vent is placed about half way between the anterior and posterior extremity, and the embryonic fin folds are comparatively much narrower. In a stage but slightly older (Plate XIII. fig. 4) the chromatophores are larger and more prominent, the pectorals have increased in size, the head has increased in length, the mouth is more anterior, the yolk bag has become much reduced, and the heart and alimentary canal have greatly increased in size. In the next stage (Plate XIII. fig. 5), the fourth day after hatching, the young Fish measures about $4^{mm}$ in length, and has greatly changed from the preceding day. The opening of the mouth is anterior, the branchial rays have been formed, the heart is divided into chambers, the stomach proper has greatly increased in size, and the intestine is better specialised than in the younger stages. The muscular bands appear well defined above and below the notochord, embryonic caudal rays are quite distinct, the permanent pectoral rays are blocked out, and the pigment cells are reduced to the three large patches described in the previous stage and a few smaller cells round the eyes and on the head. A small but prominent pigment spot has made its appearance near the end of the notochord on the lower side of the body. The stages intermediate between Plate XIII. fig. 1, and Plate XIV. fig. 1, were not traced. In Plate XIV. fig. 1, the caudal is well developed, showing but a slight trace of its ganoid lobe. The head is much larger, the body comparatively stouter, the mouth anterior, the branchiæ well developed, and important changes have taken place in the size of the stomach. In the next stage (Plate XIV. fig. 2), measuring $6^{mm}$ in length, the snout has become more pointed, and the body is quite broad and comparatively much flattened.

The spinal apophyses, of which a few could be seen in the preceding stage, are large and well developed, the dorsal and ventral muscular bands have become most prominent, there is a trace of the origin of the ventrals, the anal and dorsals are separated from the caudal embryonic lobe by a deep narrow slit, and in both these fins, as well as the caudal, the permanent rays have begun to be formed, being most advanced in the caudal fins. There are two gigantic black chromatophores extending over the dorsal part of the stomach, three prominent chromatophores of the same color in the posterior flanks of the body immediately in the line of separation of the dorsal and anal from the caudal lobe, and the remnant of a small black pigment patch at the base of the caudal rays. On the top of the cerebrum there is a patch of black pigment, and also on the anterior part of the dorsal line near the base of the brain. The general color of the young fish at this stage is yellowish, with brilliant yellow patches surrounding the dark patches of black chromatophores; the eye is of a dull blue color, with a black band above the pupil. In the next stage (Plate XIV. fig. 3), measuring $6.5^{mm}$ in length, the caudal fin has lost its ganoid lobe and has become symmetrical; the cleft separating the dorsal and anal from the caudal lobe has completely isolated them from the caudal; the snout has lengthened somewhat, the pectorals and ventrals have become larger. The principal difference in the appearance of these two stages consists in the great development of closely packed chromatophores, which cover uniformly the whole body and the posterior part of the head. The fins alone are as yet free from them; but at the base of the dorsal and anal there is a prominent continuous line of black pigment cells, and a few small inconspicuous chromatophores at the base of the caudal rays. The next stage (Plate XIV. fig. 4), but slightly older than Plate XIV. fig. 3, measuring $7^{mm}$ in length, differs from it mainly in the absence of the coating of chromatophores. There are, as appears from this stage (Plate XIV. fig. 4), from that of Plate XIV. fig. 3, and from the subsequent stage figured, three sets of coloring characterized by the extremes here figured. One as in the stage of Plate XIV. fig. 3, with densely packed dendritic chromatophores; the other, fig. 4, with only a few prominent patches of large chromatophores, and the intermediate stage (Plate XIV. fig. 5), measuring $11^{mm}$ in length, in which we have the large prominent patches (Plate XIV. fig. 5), with the band of continuous pigment cells along the base of the dorsal and anal, and the body uniformly covered with comparatively small pigment spots. This will probably account for the great differences already noticed in the youngest stages (Plate XIII. figs. 4, 5, 6, and Plate XIII. 1, 2, 3) in the presence or absence and distribution of the dendritic chromatophores. We might naturally expect such a difference from the innumerable variations in coloring noticed in the adult Ctenolabrus. During a single season at Nahant, the late Professor Agassiz had no less than sixty colored sketches made of specimens of this species, measuring from three to four inches in length, illustrating differences in the coloring or markings. In younger stages, when the young Ctenolabrus measures not more than $15^{mm}$ in length, I have found fully as great a variety in the types of coloration as among the adult; the principal types of coloring varying from a perfectly uniform light green tint to a mottled and banded pattern, which recalls far more Julis than the usual pattern of design and coloring found in our Ctenolabrus. The next stage figured (Plate XV. fig. 1) is but slightly more advanced than Plate XIV. fig. 5; it belongs to the light-colored type. The principal differences to be noticed are the nearly complete disappearance of the caudal embryonic fold and the formation of a rudimentary anterior spiny part of the dorsal. In a young Ctenolabrus (Plate XV. fig. 2) measuring $11^{mm}$ in length, this anterior part of the dorsal is somewhat more developed; the urostyle is much smaller. This specimen belonged to a type of coloring of which the adult has patches of darker color along the dorsal and ventral lines, these patches also extending over the anal and dorsal fins. The darker chromatophores are black, those of the dorsal fin and along the dorsal are of a light-brown color, and the whole upper part of the body and head is colored a brilliant yellow. In a young Ctenolabrus measuring $15^{mm}$ in length the anterior part of the dorsal has greatly increased in height, the posterior ends of the dorsal and anal have become rounded, and there is no trace of the rudimentary caudal embryonic fin. Young specimens of the same length were either uniformly covered by closely packed brownish or black chromatophores on a reddish-brown or greenish background, or else the darker chromatophores were arranged in bands, slanting from the median line towards the tail, with irregular patches at the base of the dorsal fin and along the dorsal side, or else they were of the pattern figured here (Plate XV. fig. 3) upon a light yellowish background.

In a somewhat more advanced stage (Plate XV. fig. 4) of about the same length as Plate XV. fig. 3, the body and head of the young Ctenolabrus have become quite compact, the fins resemble in outline those of the adult, and the young Ctenolabrus has practically assumed the principal characteristic features of the older and larger fish. Fishes in the stages of Plate XV. figs. 2–4, are still pelagic, though many of them can be caught in the eel-grass or kelp along with the older fishes.

The young Ctenolabrus at a very early age assume the peculiar slanting of the body which the older fish take specially when feeding or when coming up to examine any object.

### MOTELLA ARGENTEA, *Rhein.*

(Plate VII. Plate VIII. figs. 1–3.)

The youngest specimen of this species I have seen (Plate VII. fig. 1) measured $4^{mm}$ in length. It was remarkable for the comparatively strong coloring for so young a stage. The head dorsal and ventral muscular lines, as well as the sides of the stomach, are of a dark dirty yellow. The pectorals are large and transparent, but the ventrals, already well developed, are of a dark maroon color. The lower part of the eye is light blue, the pupil of a dark crimson. About half way between the tail and pectorals there are two large pigment cells, one in the dorsal, the other in the ventral side of the notochord. A smaller cell indicates the position where the embryonic caudal fin rays are forming.

There are three pigment cells on the brain, the largest in front, two smaller ones at the extremity of the snout, one on the lower and one on the upper jaw, with a still smaller cell at the base of the operculum. Four to five larger cells form a black edge to the upper side of the stomach. In a somewhat older stage (Plate VII. fig. 2) the principal differences consist in the greater size of the pectorals, the larger ventrals, the increase in size of the chromatophores on the head and stomach, and the greater elongation of the snout. Seen from above (Plate VII. fig. 3) the ventrals appear like wings proportionally as large as the pectorals of the young Flying-Fish. In a young fish measuring $7^{mm}$ in length (Plate VII. fig. 4) the pectorals have increased but little in size since the preceding stage. The ventrals are nearly one third the length of the fish. The head, quite rounded above, is proportionally larger, and the body much wider and less elongate than in the younger stages (Plate VII. figs. 1–3).

The chromatophores are more numerous in the upper part of the head and on the upper part of the stomach, while the single cell of the dorsal region half way to the tail has increased to a large patch of chromatophores, and forms in this stage the largest accumulation of pigment cells. The permanent rays of the caudal fin are well advanced, and at the base of each is placed a minute pigment spot. The permanent rays of the dorsal and anal are also commencing to form, but they are far less advanced than those of the caudal. The embryonic fin rays are still to be traced in that part of the fin fold which unites the caudal lobe with the dorsal and anal. The coloring of this stage is greener than in the preceding stages; the greenish tint is especially marked on the upper part of the head and near the dorsal patch of chromatophores. The ventrals are somewhat darker colored than the younger stages. In all the stages thus far figured the young fish swims mainly by means of the powerful stroke of the ventrals, which they spread like wings laterally to their fullest extent at right angles to the body. In a somewhat more advanced stage (Plate VII. fig. 5), measuring $12^{mm}$ in length, the body has increased greatly in length, the pectorals are longer, the ventrals are less than one-fourth the length of the body; the caudal has become terminal and rounded, and quite well separated from the dorsal and anal; the permanent fin rays are well developed in the three median fins; the head has become lengthened, and the pigment spots of the upper part of the head and anterior part of the body are smaller and more numerous than in the preceding stages.

The chromatophores along the dorsal line and base of the dorsal and anal are now arranged in longitudinal lines. The coloring of the body behind the anterior base of the dorsal, as well as the head, has assumed a yellowish-green tint slightly bluish towards the ventral side.

In a subsequent stage (Plate VII. fig. 6), but slightly older, the greenish color of the dorsal part of the fish has become more marked, and there exists a principal lateral line of black chromatophores extending from the operculum nearly to the posterior extremity of the dorsal; the extremity of the body near the caudal is still quite transparent, of a yellowish tint, showing the ganoid termination of the notochord. The ventrals in this stage are proportionally longer again than in Plate VII. fig. 5, being somewhat more than one quarter the length of the fish. Viewed from above, the young fish is often seen with ventrals spread at right angles, as in Plate VIII. fig. 1 *a*, or flapping them violently up and down when excited, or as in Plate VIII. fig. 1, when swimming rapidly. In a somewhat older stage (Plate VIII. fig. 2) the dorsal and anal fins are well separated from the caudal; the anterior dorsal has commenced to form; the ventrals have lost somewhat their wing-like character, they are usually carried folded, and appear more like long fin rays; the head has lengthened, is more rounded, sloping anteriorly; the pectorals are elongated, and the greenish blue color of the body is limited to the dorsal regions, the sides being silvery; a colored belt, slightly greenish, extends along the base of the anal. In the oldest pelagic specimen of young Motella (Plate VIII. fig. 3) the barbel of the lower jaw is well formed, the anterior dorsal is higher than the posterior dorsal, the ventrals are long fin rays equalling in length one third of the length of the young fish, the greenish blue color of the dorsal region is more intense than in the younger stages, and extends in slightly lighter-colored diagonal bands across the flanks; the posterior part of the dorsal, of the anal, and the base of the caudal are marked with small black pigment spots at the base of the permanent fin rays. In this stage and in the one immediately preceding (Plate VIII. fig. 2) the young fish make but little use of their ventrals while swimming. The extremity of the caudal is cut quite sharply at right angles to the longitudinal line, with slightly rounded corners. At this stage the resemblance to Bregmaceros is striking.*

### GADUS MORRHUA, *Lin.*

(Plate VIII. figs. 4, 5.)

The only other Gadoid of which I have found the young by fishing on the surface is probably our common Cod; when only $28^{mm}$ in length it has in this early stage (Plate VIII. fig. 5) assumed all the characteristic features of the genus. The only other young stage I have seen is a young Cod measuring $20^{mm}$ in length (Plate VIII. fig. 4), which differed from fig. 2 in not having a barbel, and in having the median fins still connected, although the three dorsal and two anals were quite distinct. The pigment cells were not arranged to form any definite pattern, but covered uniformly the dorsal region. The breaking up of the continuous embryonic dorsal and anal into separate fins is admirably seen in the stage represented in Plate VIII. fig. 4.

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* Emery in his monograph of Fierasfer has also figured the pectorals of the young Merlucius and Motella. There is still some uncertainty with regard to the genus to which the specimens I have here referred to Motella belong; they may prove to be one of the species of Onus described by Collet.

## FUNDULUS NIGROFASCIATUS, *C. & V.*

(Plates XIX. XX.)

Sundevall has already given the principal changes of form which Cyprinus undergoes while passing from its leptocardial stage to that of the adult. I have traced the principal changes of growth in one of our species of Fundulus, and find they agree fairly with the stages figured by Sundevall. That in the youngest stages the crossopterygian nature of the pectorals is owing to their large size is perhaps as striking as in any other embryo of osseous fish known to me. (See Plate XIX. figs. 5, 6, in which are given a view of the pectorals, fig. 6, from above; partly in profile, fig. 5; and a side view of a large pectoral (fig. 4), in which the fleshy base and the embryonic rays of the fin are best developed just previous to the appearance of the first trace of the permanent fin rays.) The gradual change of the pigment cells from a linear arrangement to the characteristic pattern of the adult is readily traced in the oldest specimens figured on Plate XX.

## OSMERUS MORDAX, *Gill.*

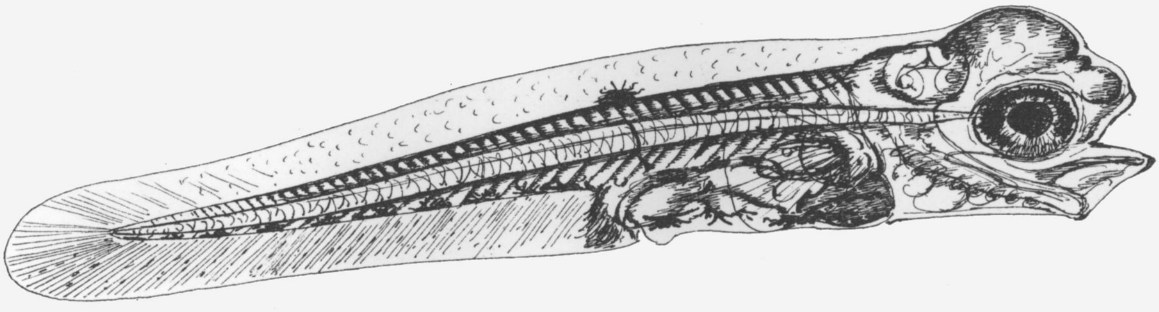
(Plate XII.)

The egg is pelagic, quite transparent; the young on hatching are about $5^{mm}$ in length (Plate XII. figs. 1, 2), with a comparatively small yolk bag, very rudimentary head, huge eyes, the vent placed at about three quarters of the length of the body near the posterior extremity, pectorals quite rudimentary. There are no pigment cells in this stage in any of the young I have collected. In the next stage figured (Plate XII. fig. 3) the young fish has greatly changed, the head is quite elongate, branchiæ are present, the lower jaw projecting beyond the upper one, pectorals large, eye brilliant emerald green, the yolk bag has completely disappeared, the caudal embryonic fin rays are very marked; we can also see the first trace of the separation between the caudal, anal, and dorsal. A prominent row of large pigment cells extends along the base of the anterior anal embryonic fin fold, with a smaller line extending along the upper side of the intestines, a few small pigment cells at the extremity of the notochord, along the base of the posterior anal and of the operculum, with two or three pigment cells along the dorsal line about half way from the head to the tail.

In the next stage figured the young Osmerus is considerably older, measuring already $22^{mm}$ in length; the caudal is completely separated from the dorsal and anal, in both of which the permanent fin rays already exist; there are rudimentary ventrals present in this stage. The general coloring of the body is a light dirty yellow, with patches of more brilliant yellow along the lateral line and base of the head. There is one line of greyish pigment spots along the dorsal side of the notochord, a very prominent line of large pigment cells running somewhat below the notochord, extending from the base of the pectorals to the vent, with four or five large pigment cells along the base of the anal and the ventral line towards the base of the caudal. Small pigment spots extend along the base of the caudal fin rays, with three or four larger spots at the base of the caudal fin. The oldest stage I have found (Plate XII. fig. 5) was not larger than Plate XII. fig. 4, but the caudal, anal, and dorsal were in a more advanced condition, the permanent fin rays better marked, the head less elongate, the body behind the ventrals comparatively broader. The great resemblance of this stage of Osmerus to Scomberesox and Belone in the general arrangement of the median fins and the great elongation of the body is striking. Mr. H. J. Rice has, in the Report of the Commissioner of Fisheries of Maryland for 1877 (Plates III. V.), given excellent figures of several young stages of the Smelt. The figures here given complement the stages already known, and with those of Mr. Rice give a fair sketch of the principal changes of the Smelt due to growth. The resemblance of the development of Osmerus to that of the Herring as given by Sundevall is very striking. Sundevall figures young fishes, which he calls embryo Herring, from 8 to $38^{mm}$ in length, but he does not state whether they were actually raised from eggs of known origin. Before the publication of Mr. Rice's paper I had already supposed the young fishes figured on Plate XII. to be the young of some Clupeoid, but the figures given by him seem to leave no doubt that the young I figure on Plate XII. belong to the Smelt.

Agassiz Young Osseous Fishes Pl. I

1



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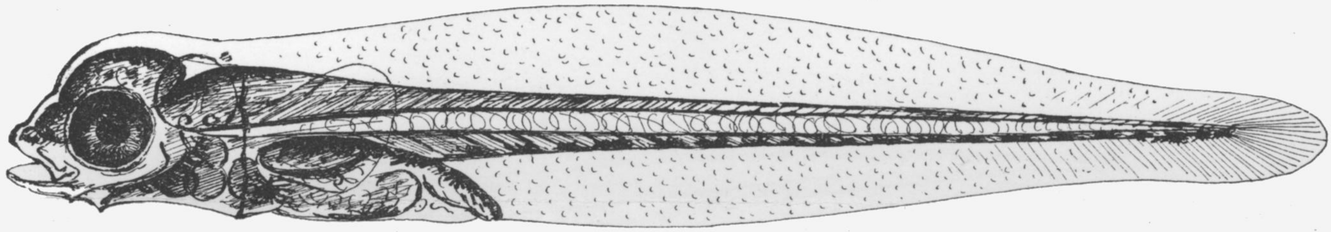

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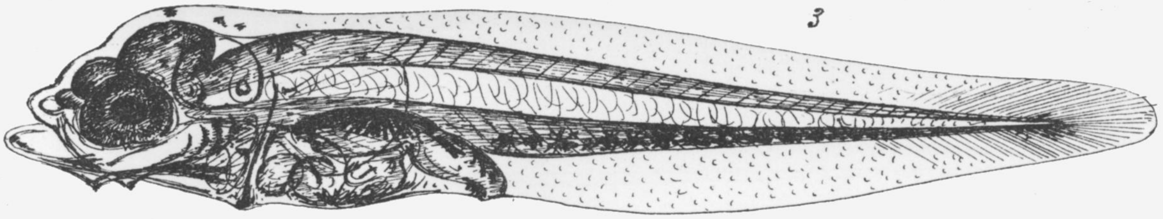

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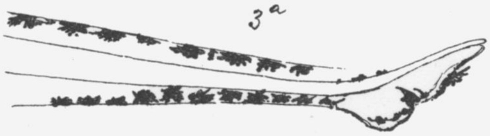

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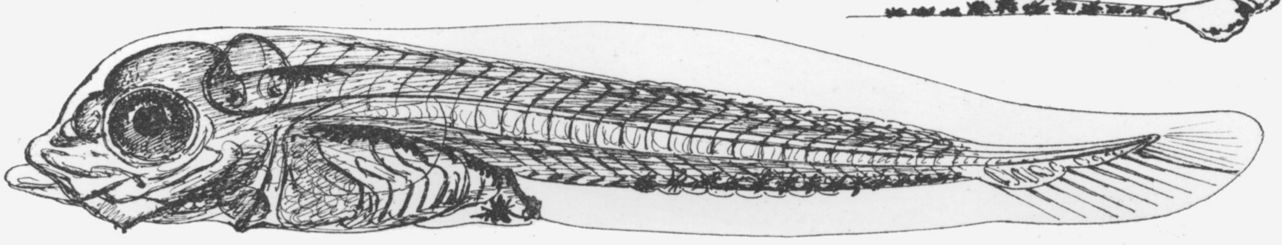

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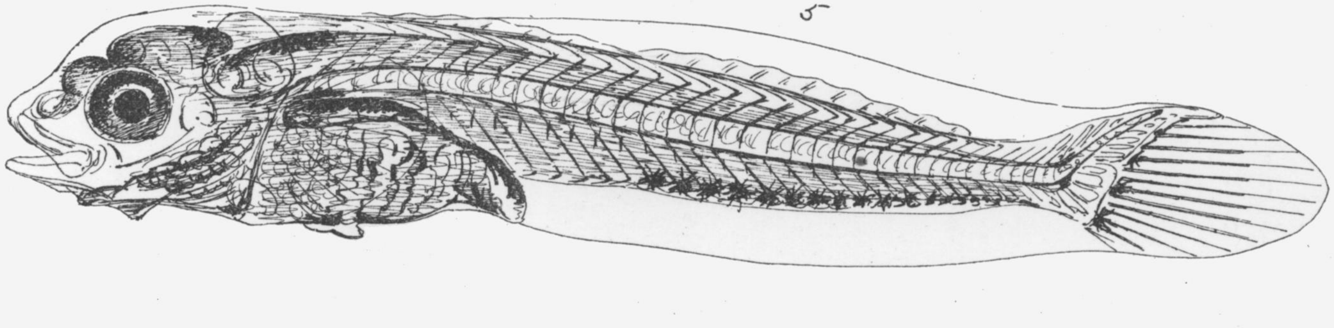

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Agassiz' Young Osseous Fishes

Pl. II

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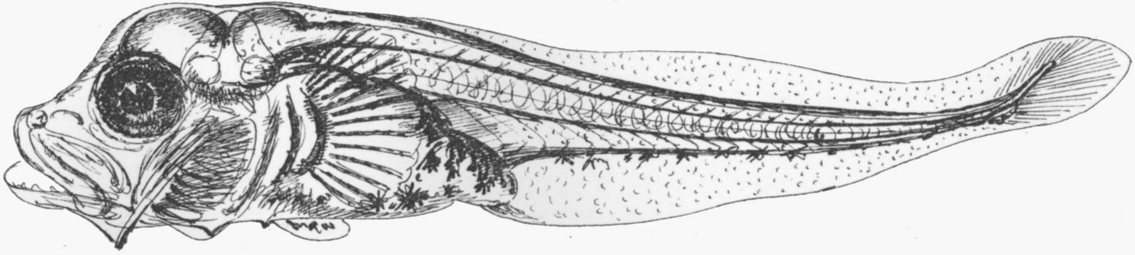

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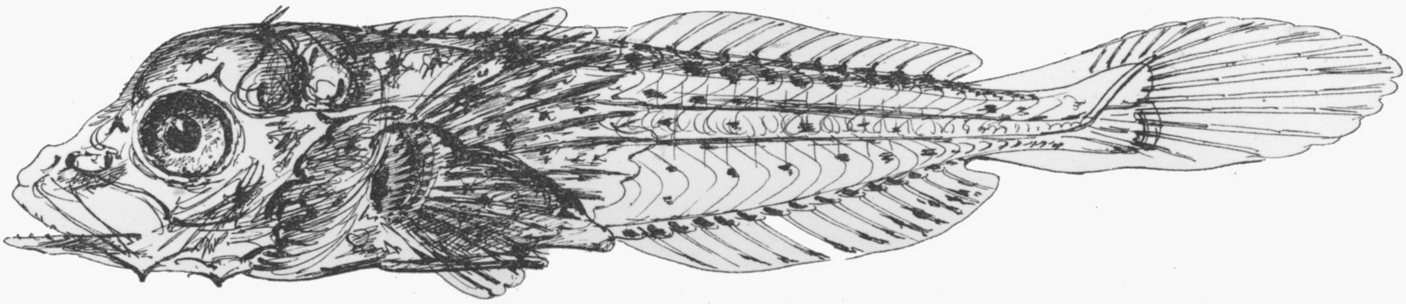

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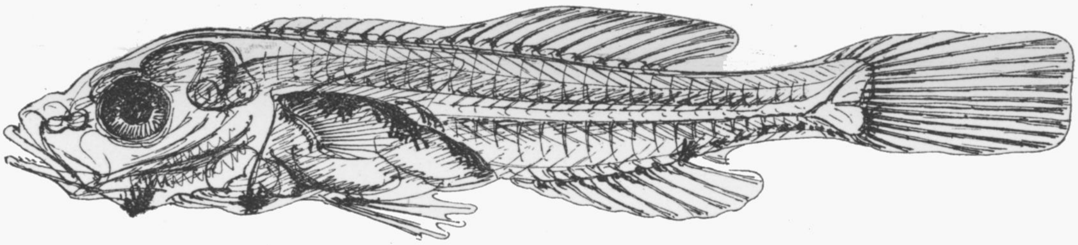

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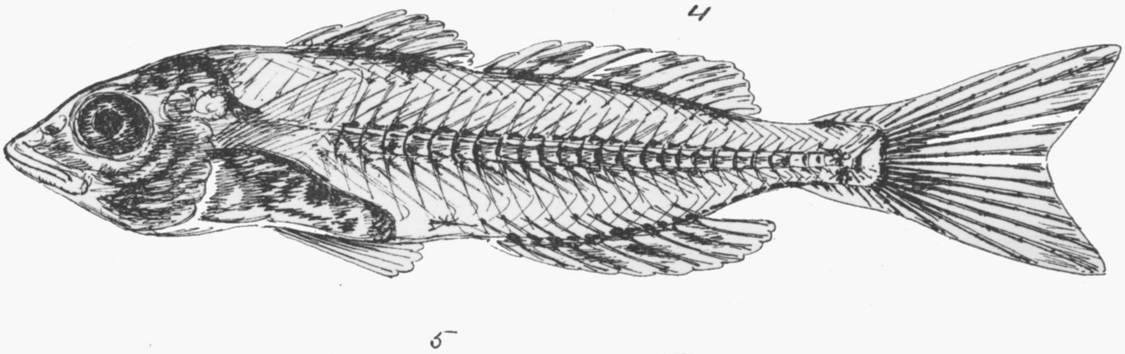

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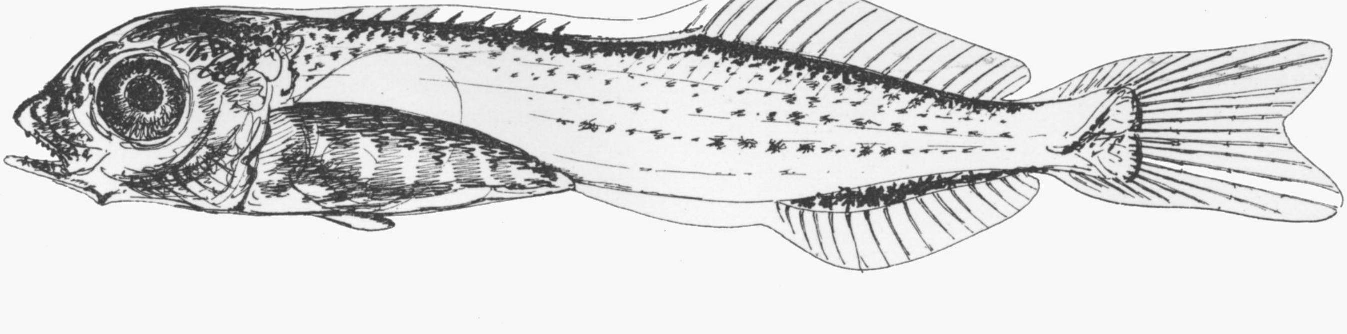

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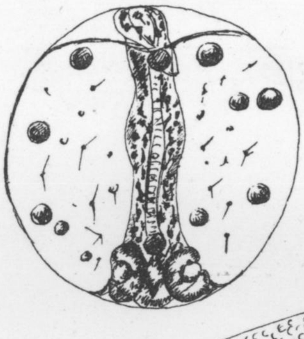
Pl. III

1



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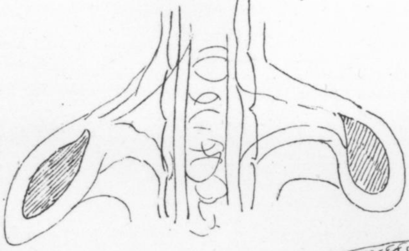

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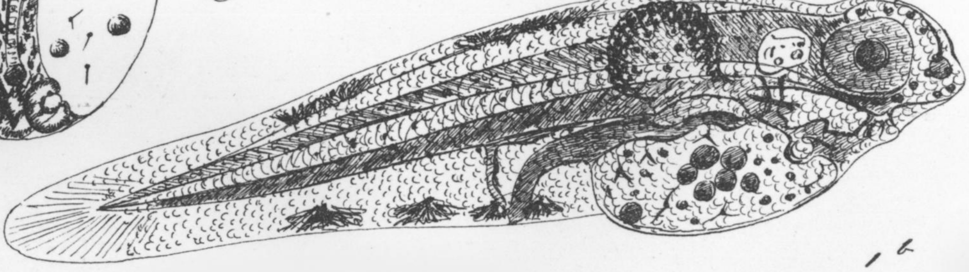

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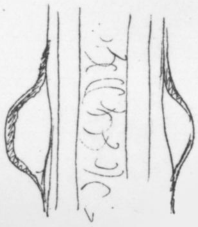

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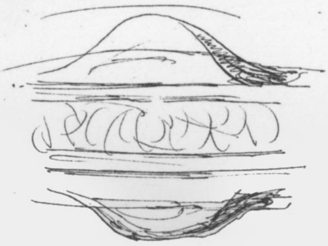

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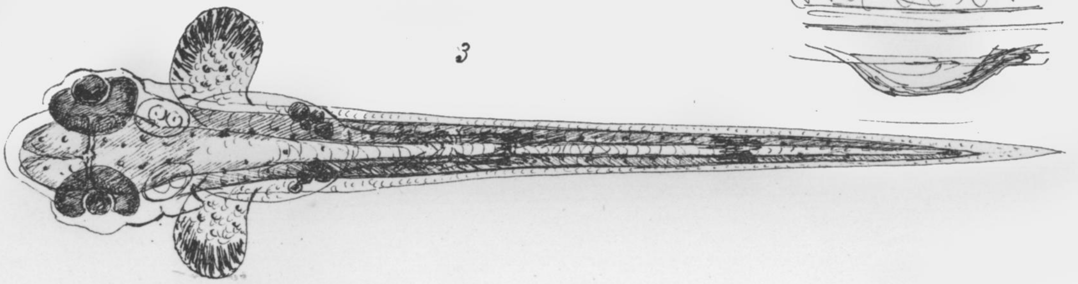

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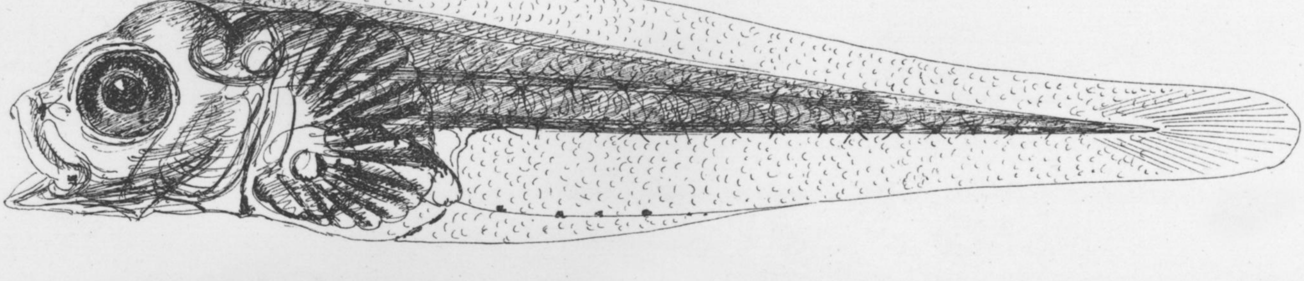

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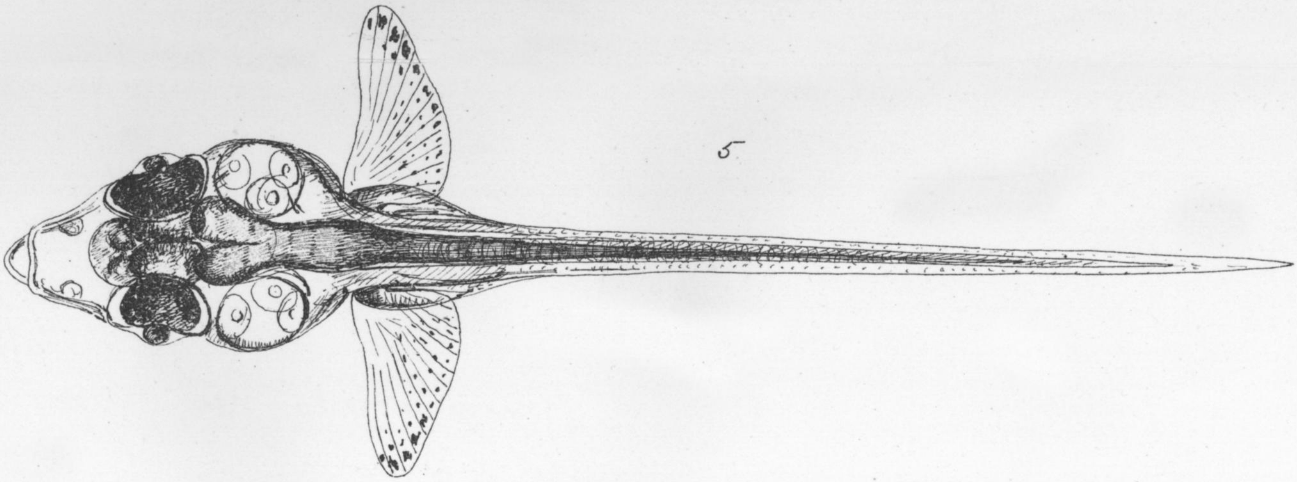

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Agassiz' Young osseous Fishes Pl. IV

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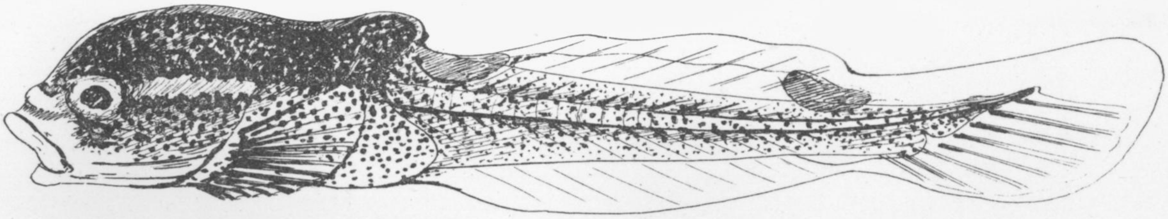

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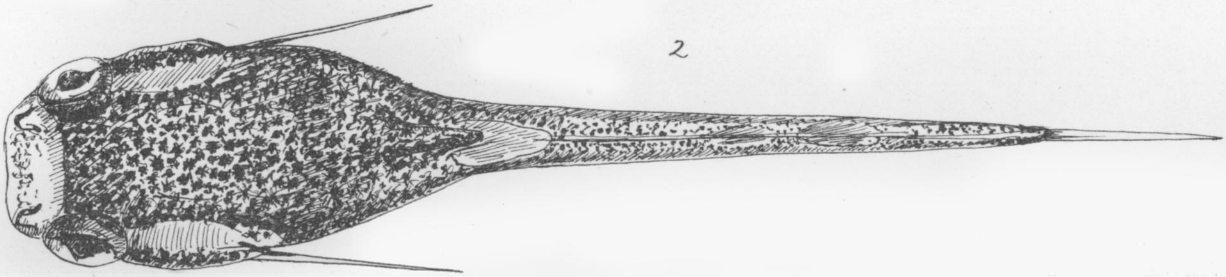

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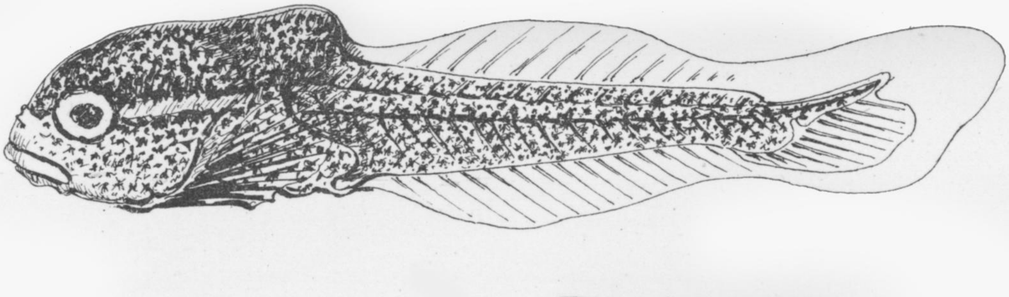

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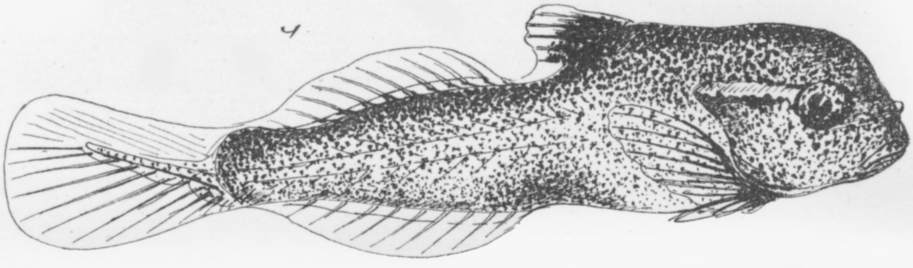

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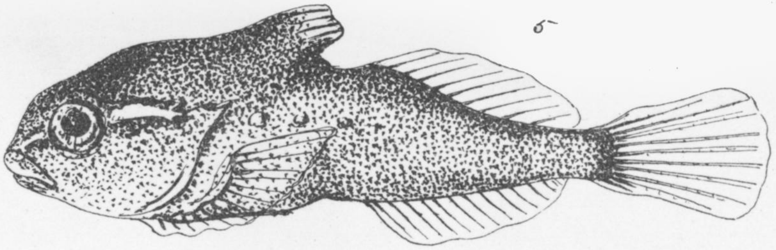

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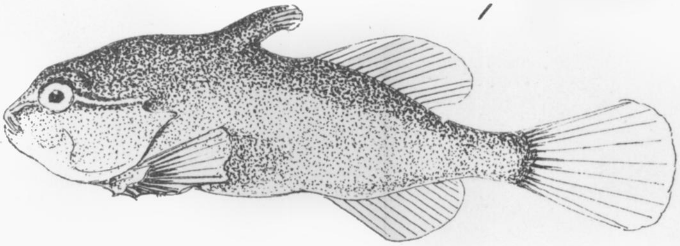
Agassiz' Young Osseous Fishes

Pl. V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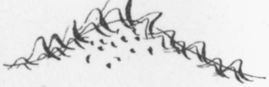
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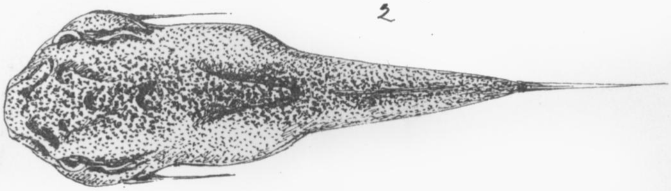
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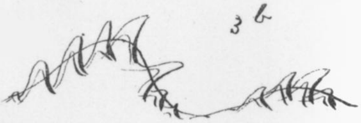
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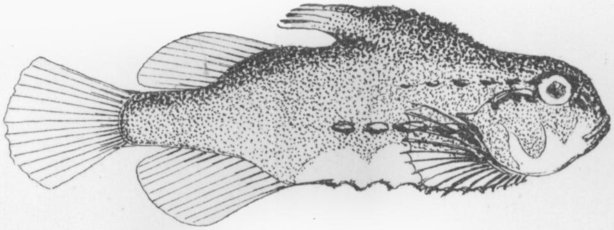
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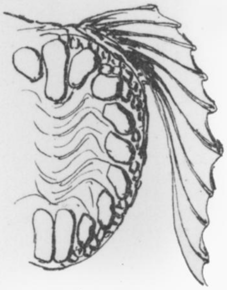
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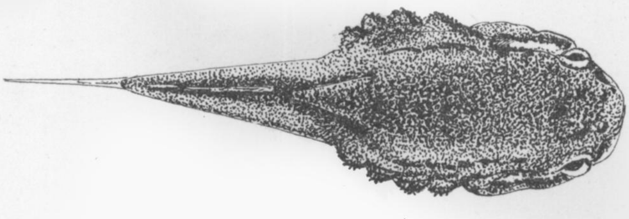
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Pl. VI

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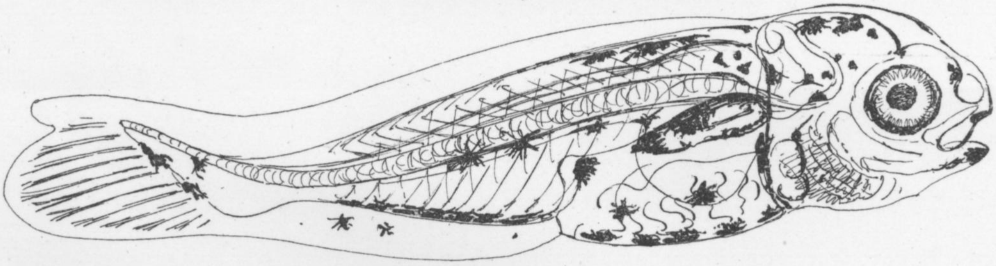

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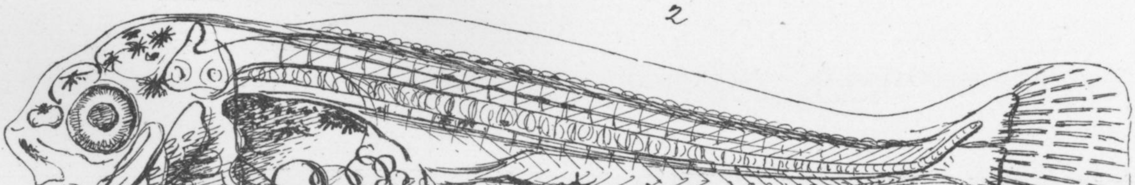

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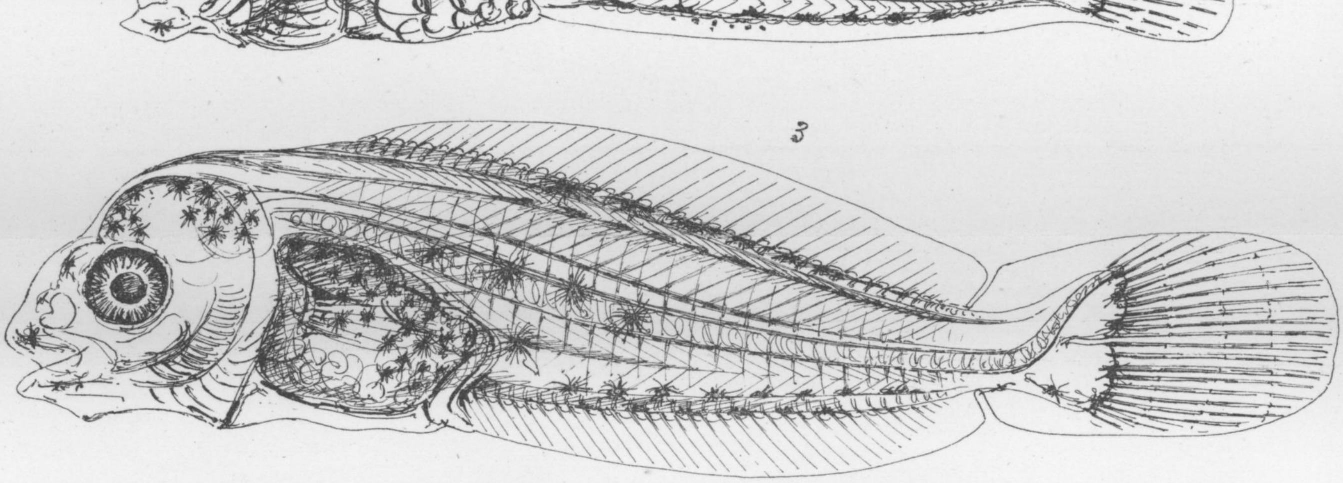

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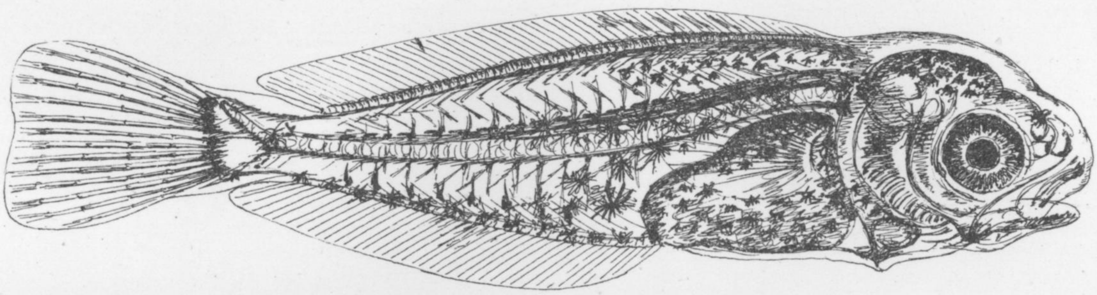

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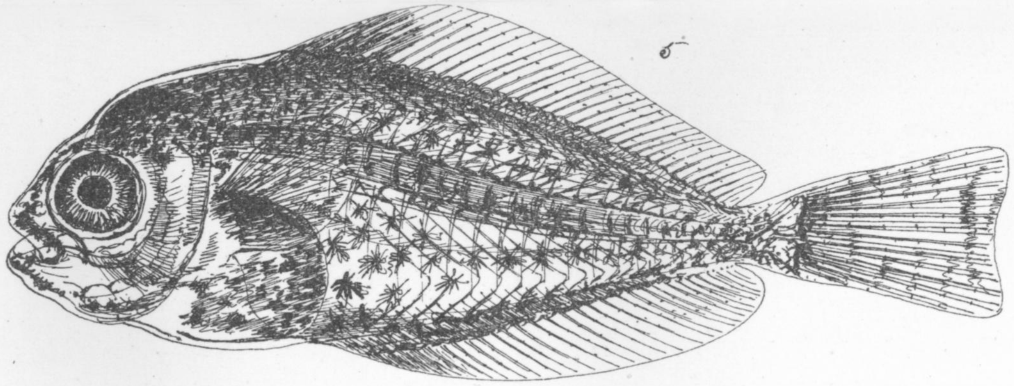

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Pl. VII

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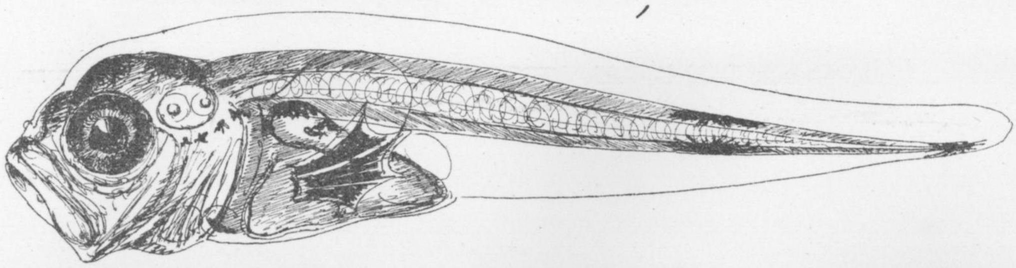

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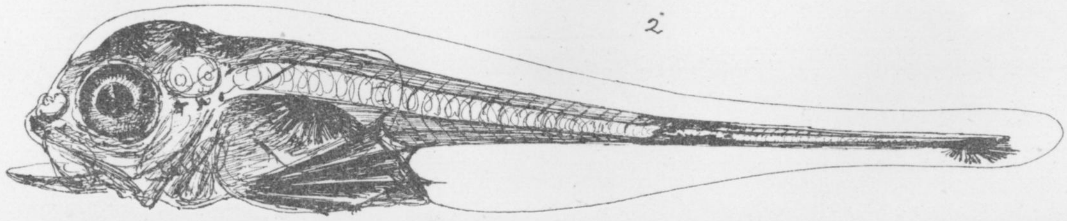

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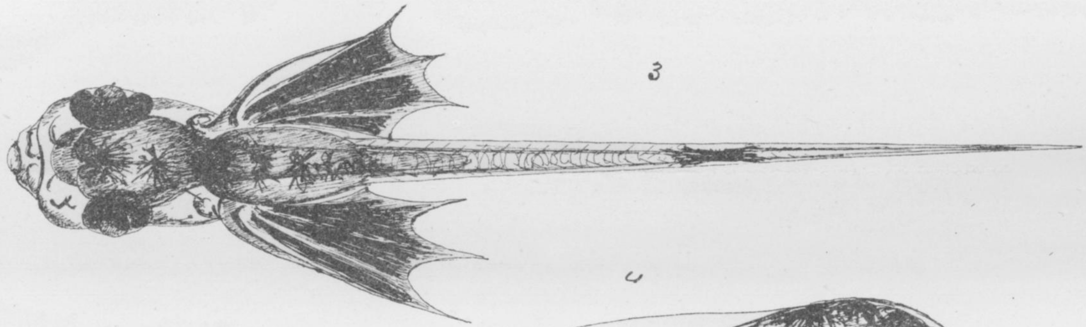

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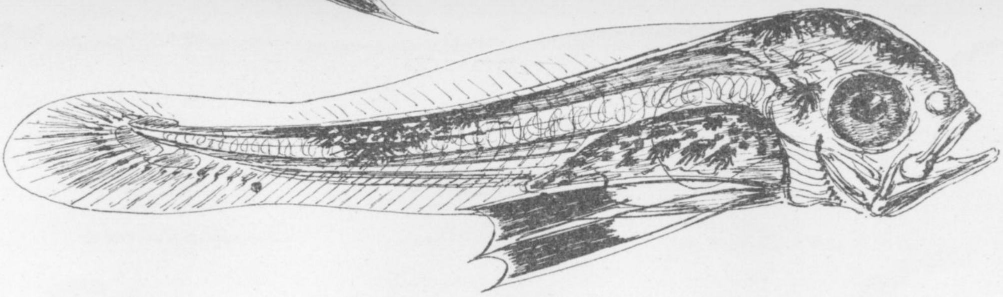

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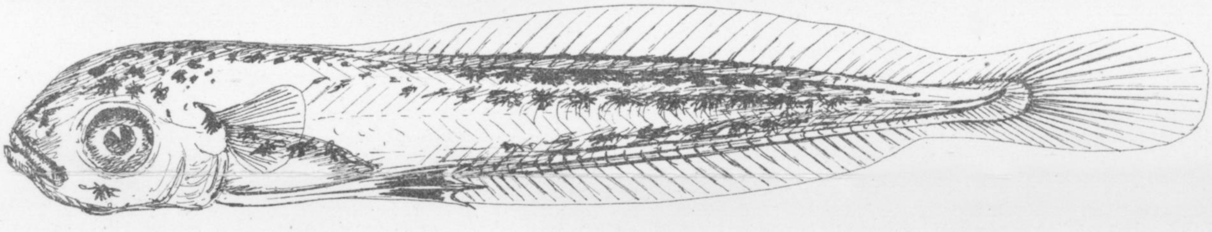

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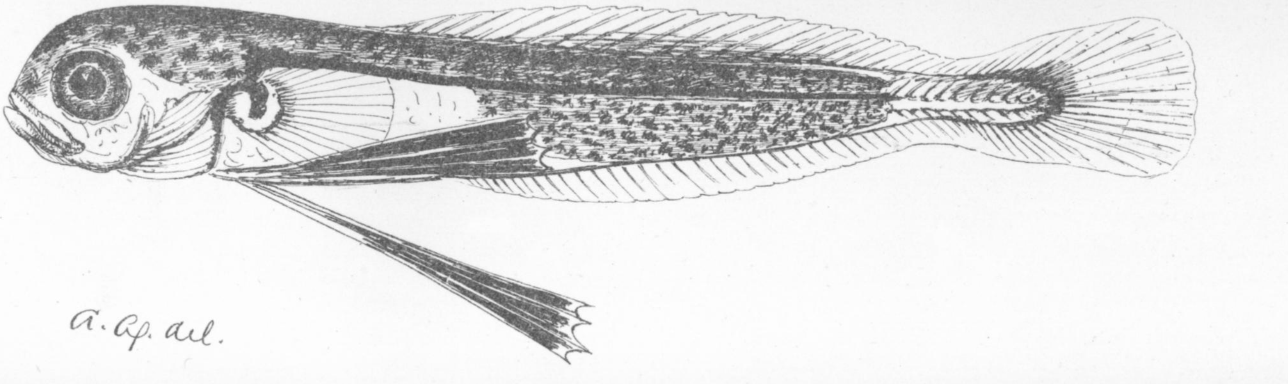

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Pl. VIII

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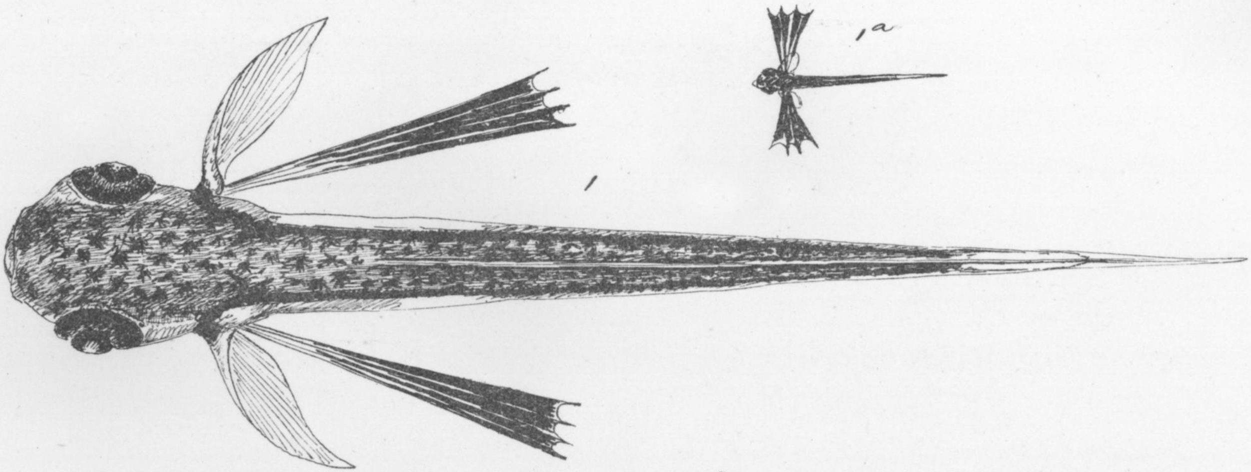

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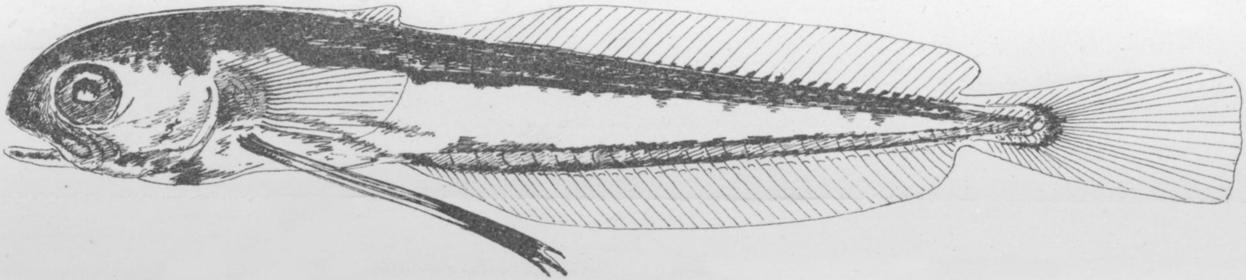

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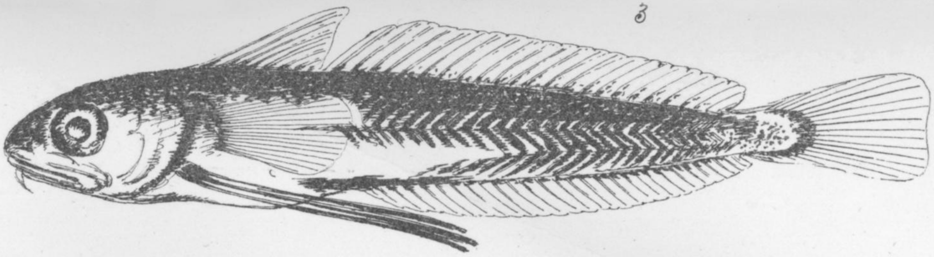

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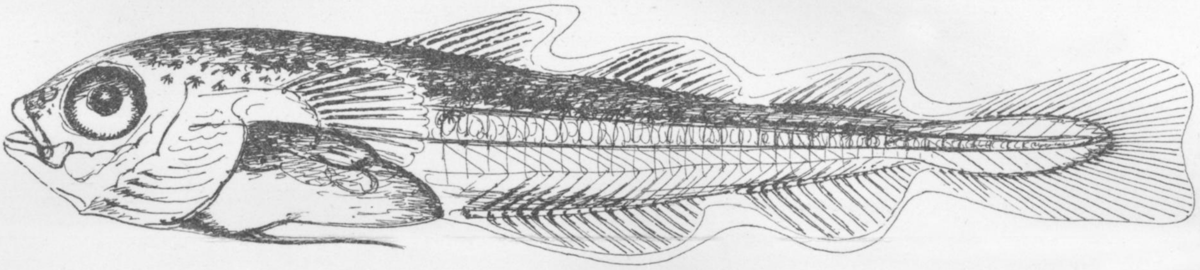

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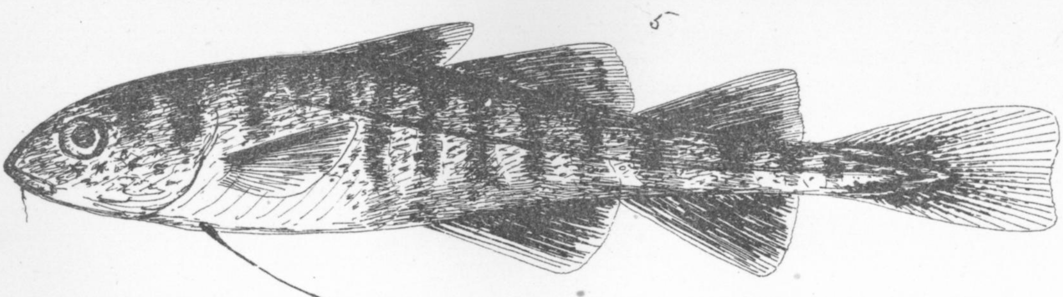

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Pl. IX

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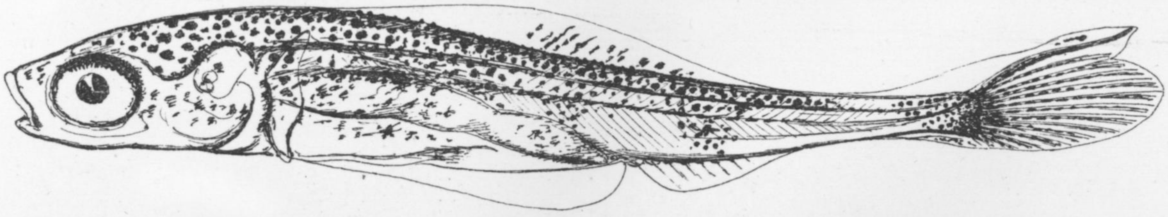

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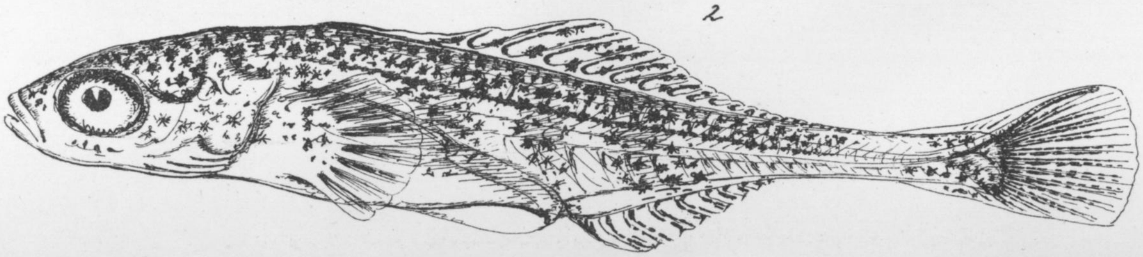

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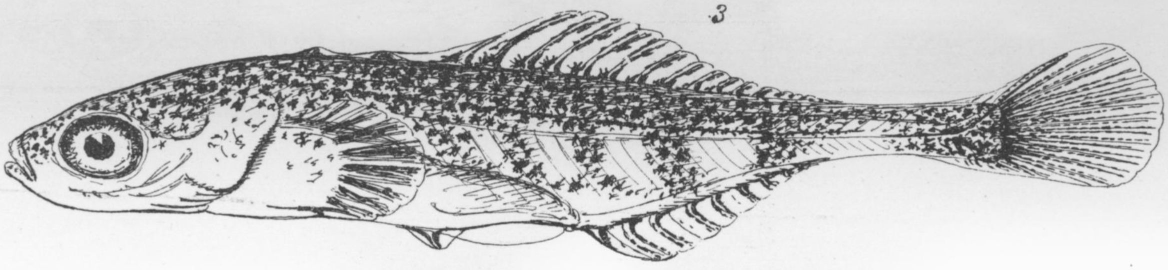

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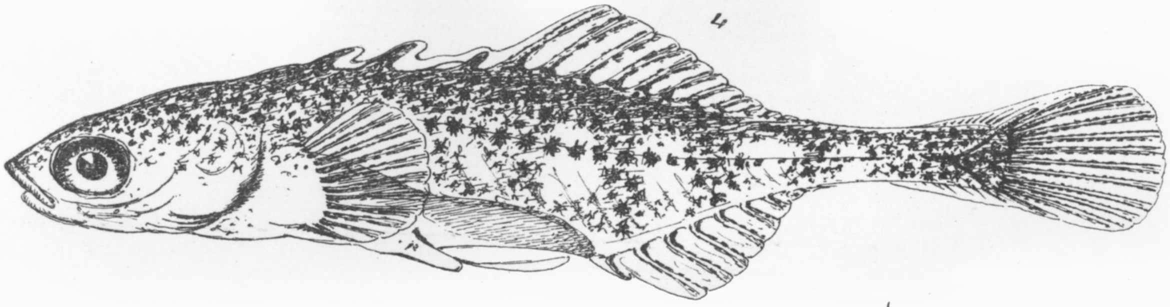

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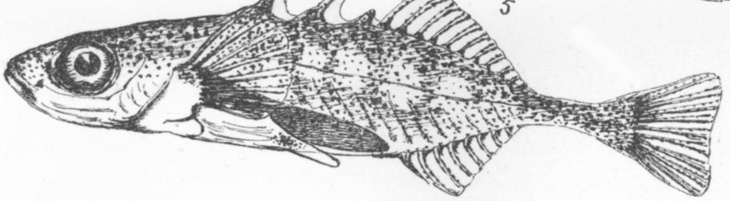

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Agassiz' Young Osseous Fishes

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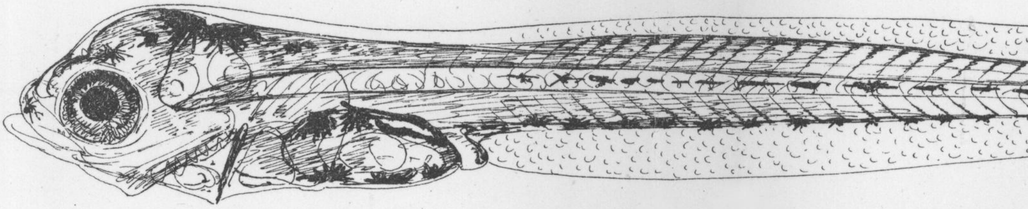

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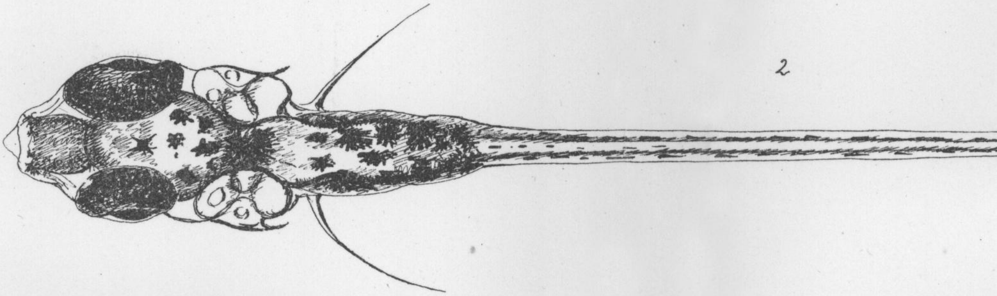

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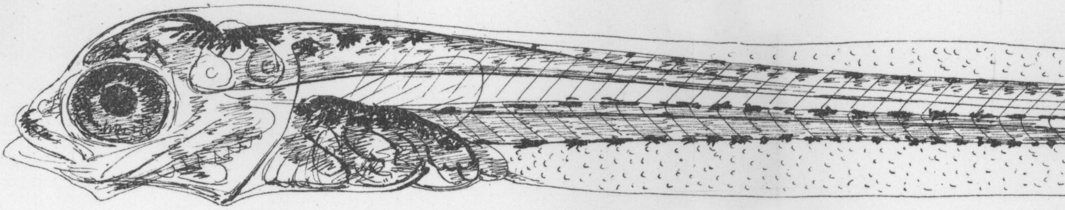

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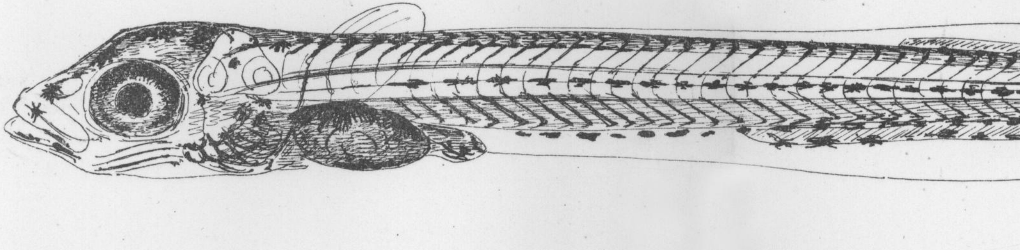

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Pl. X

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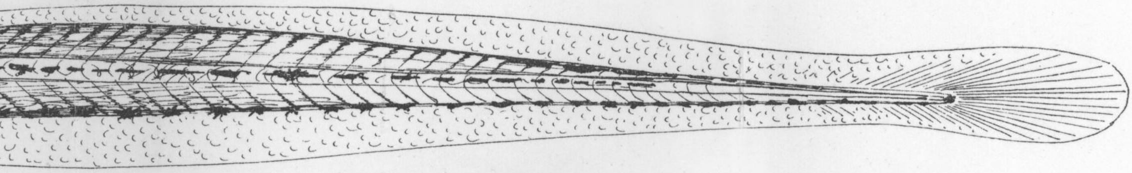

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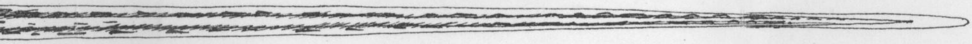

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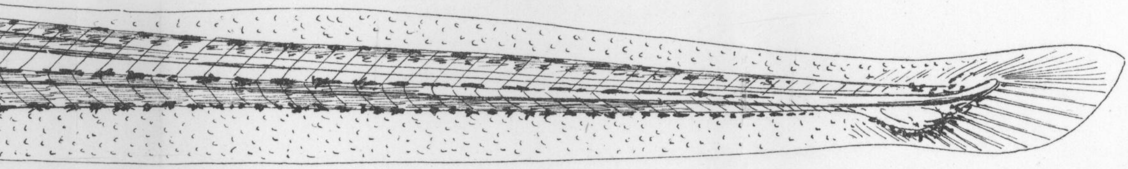

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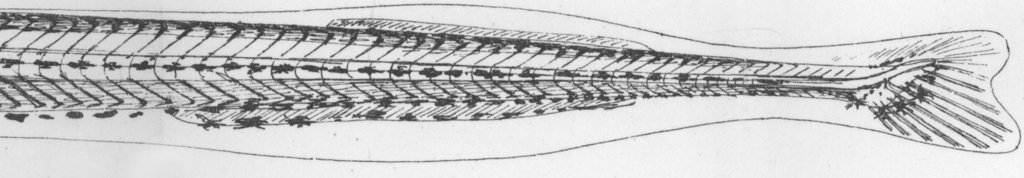

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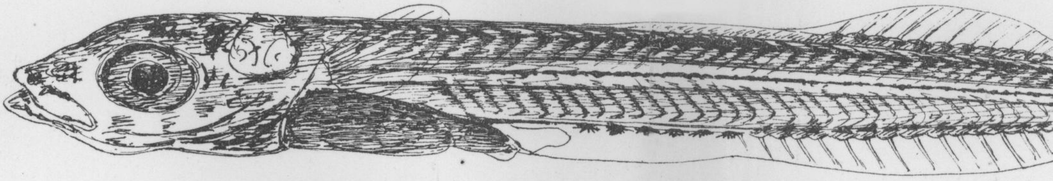
Agassiz' Young Osseous Fishes

5



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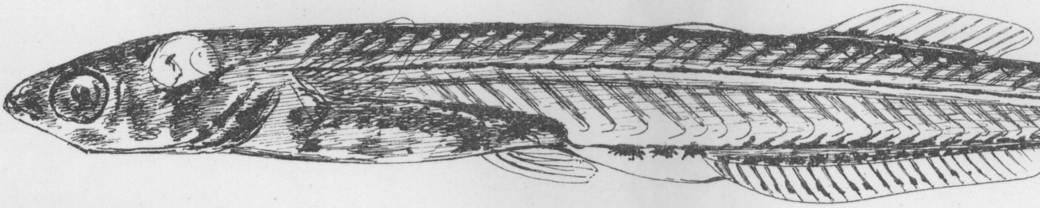

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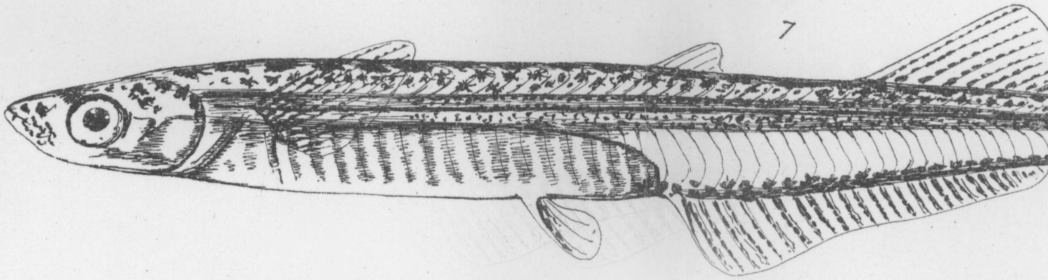

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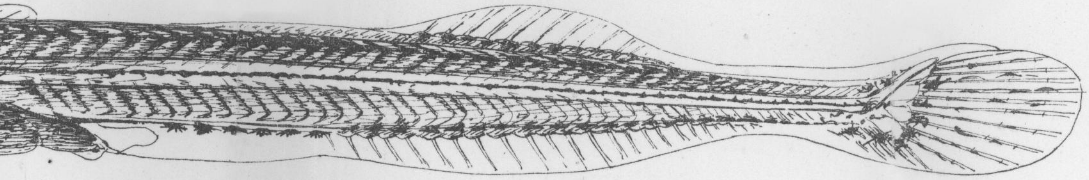
Pl. XI.

5



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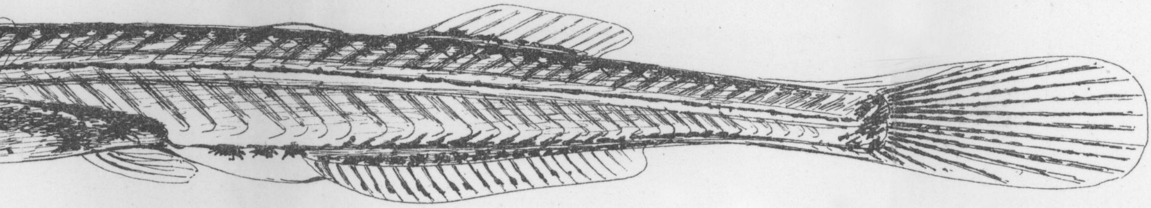

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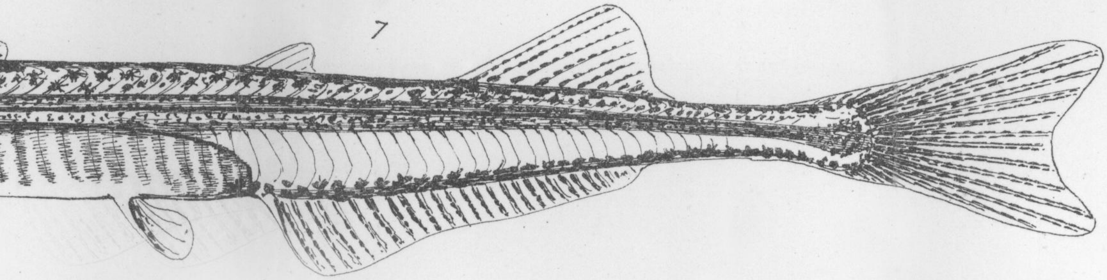

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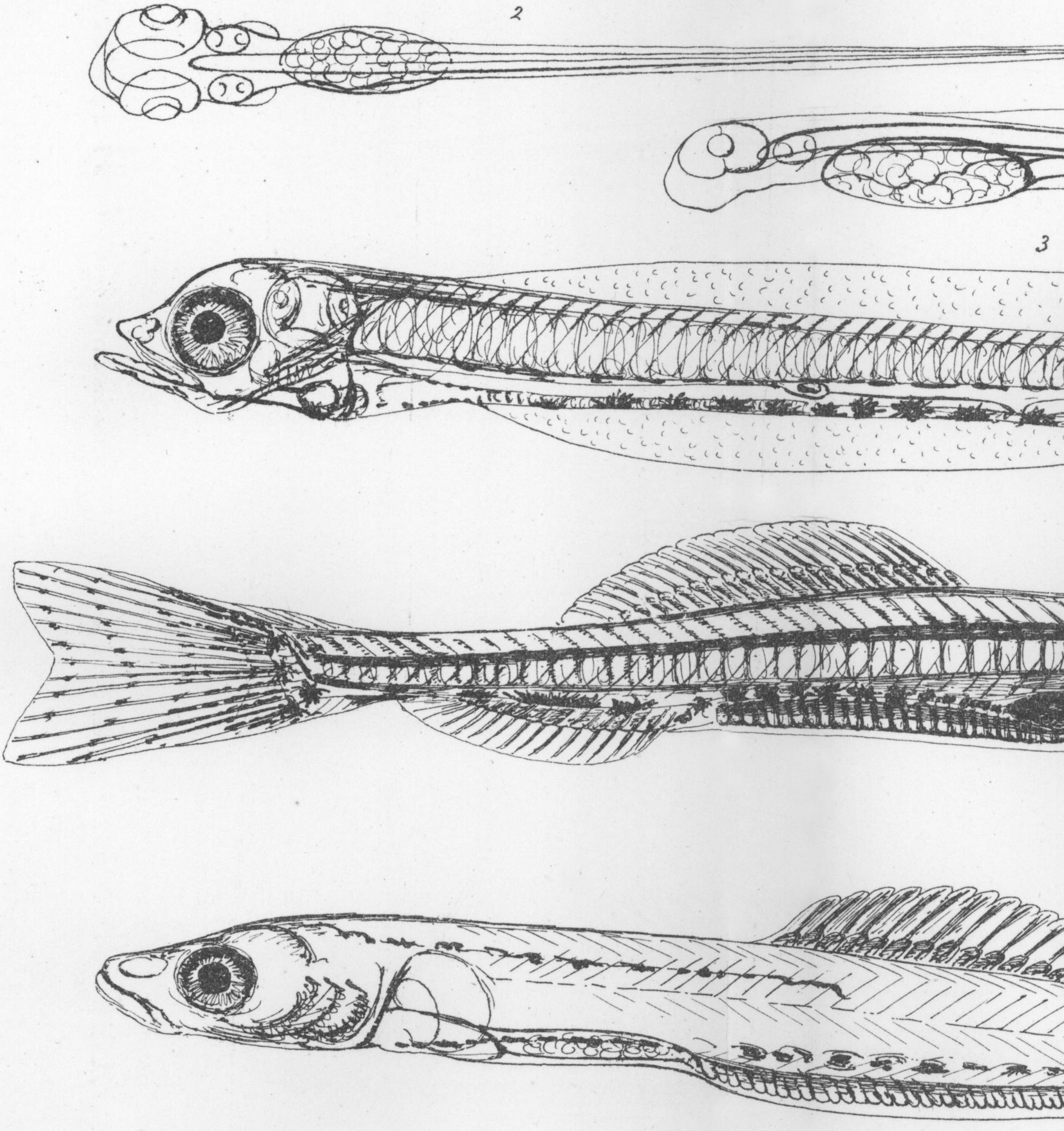

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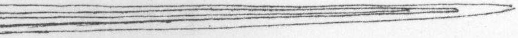
Pl. XII.



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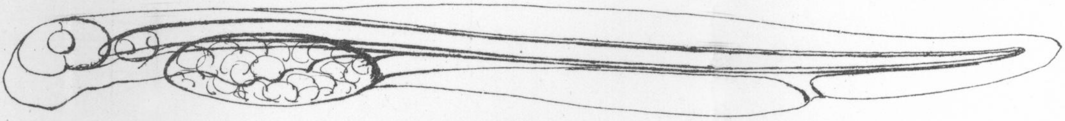

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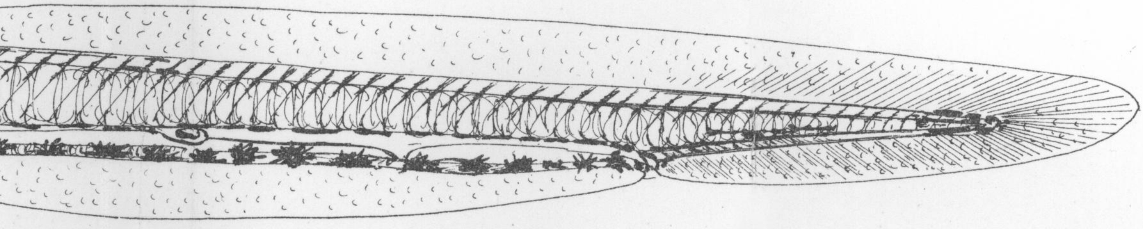

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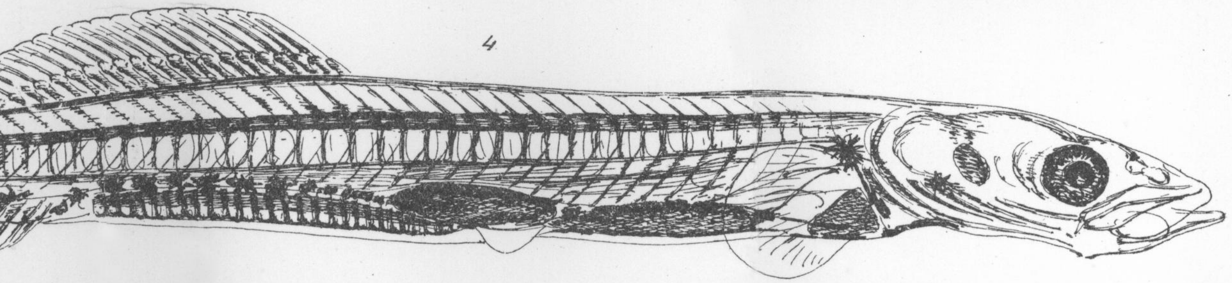

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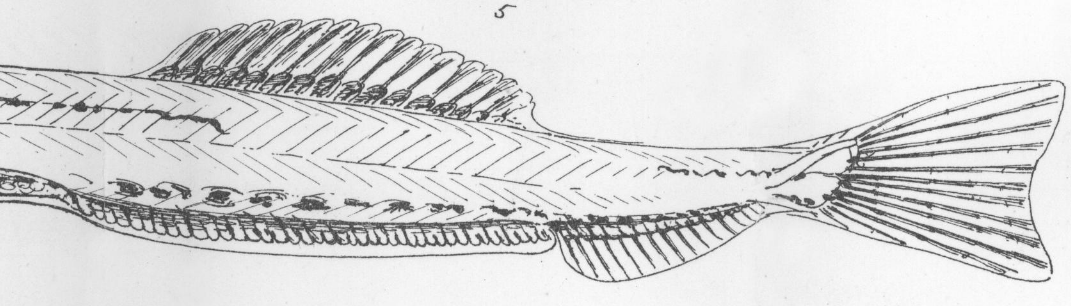

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Pl. XIII

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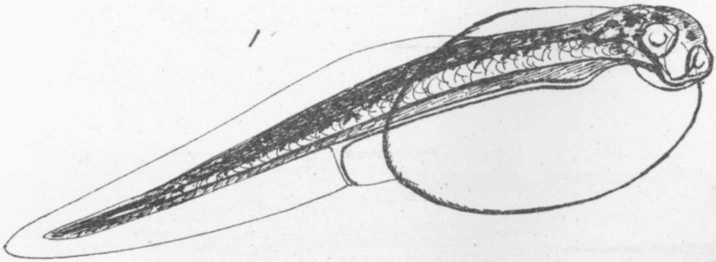

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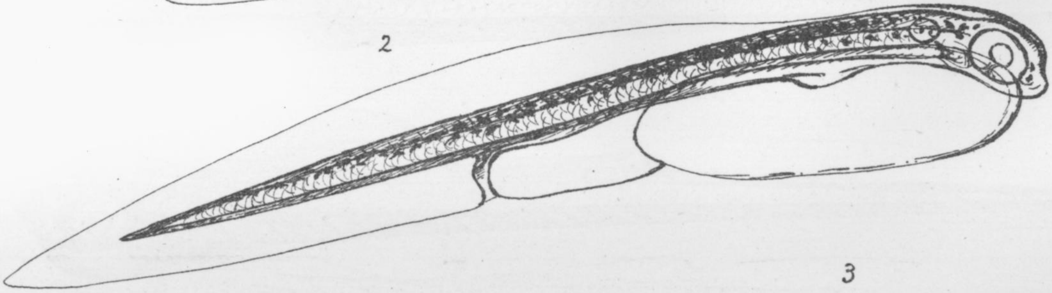

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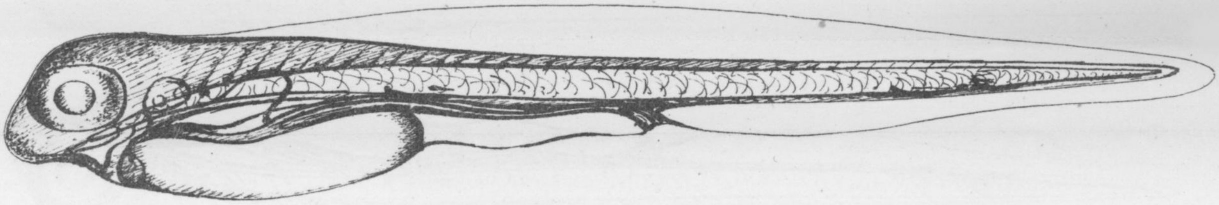

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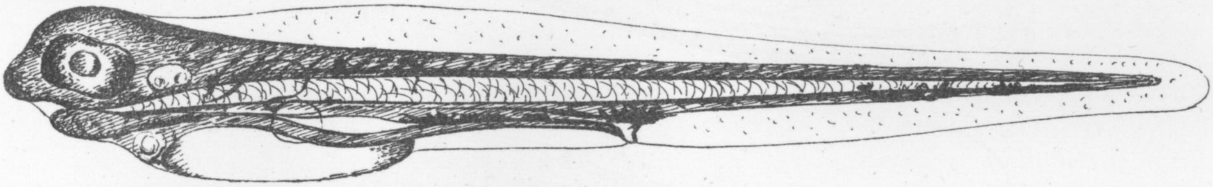

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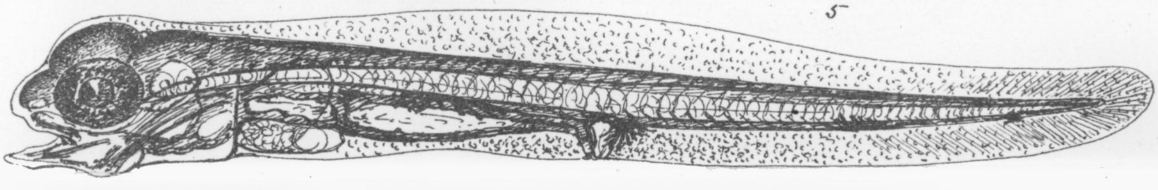

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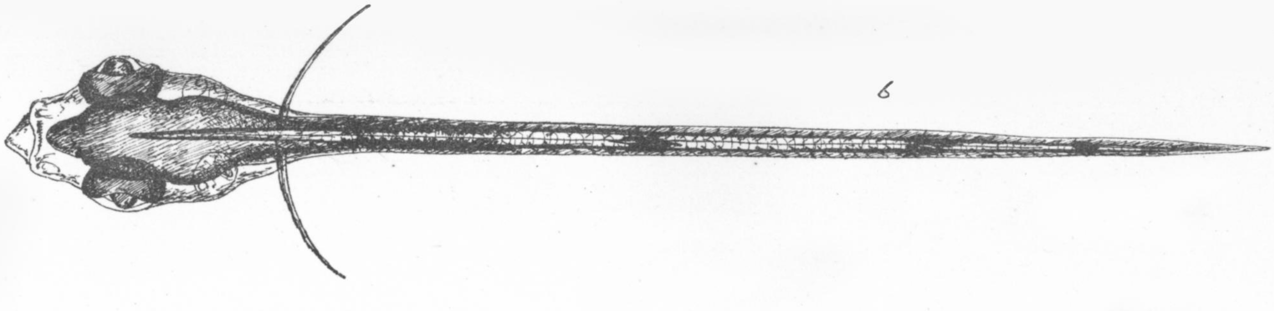

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Pl XIV

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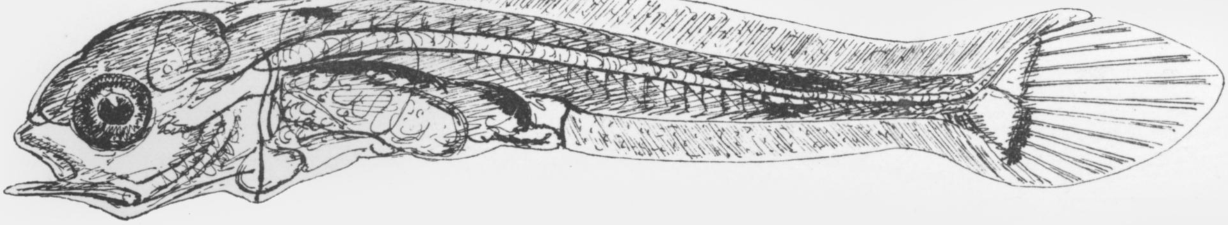

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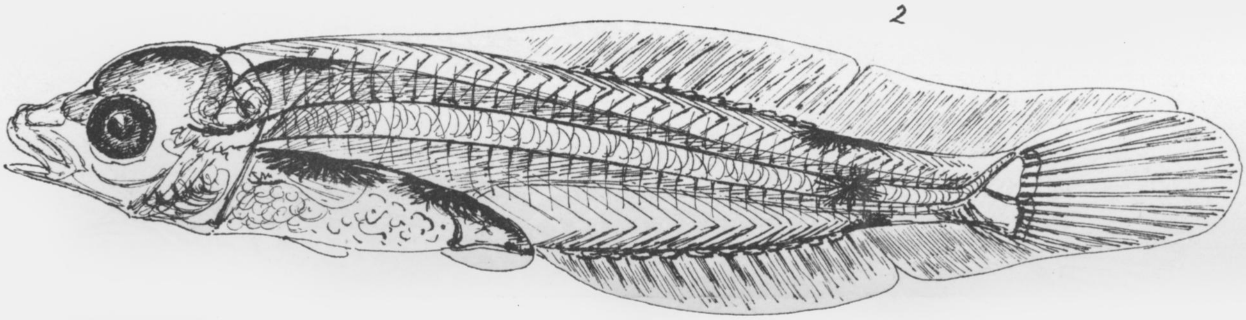

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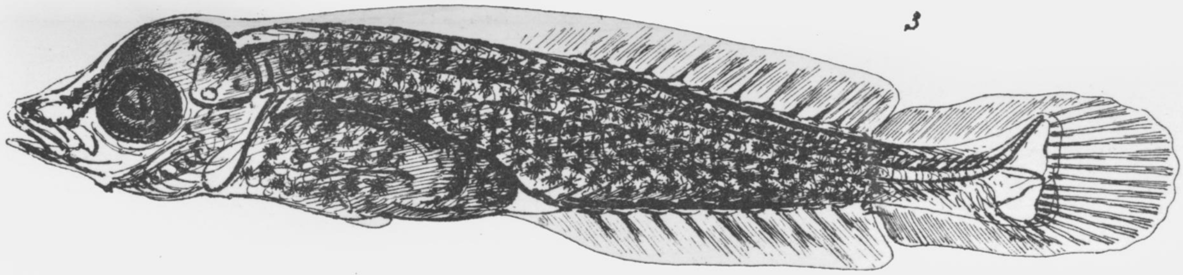

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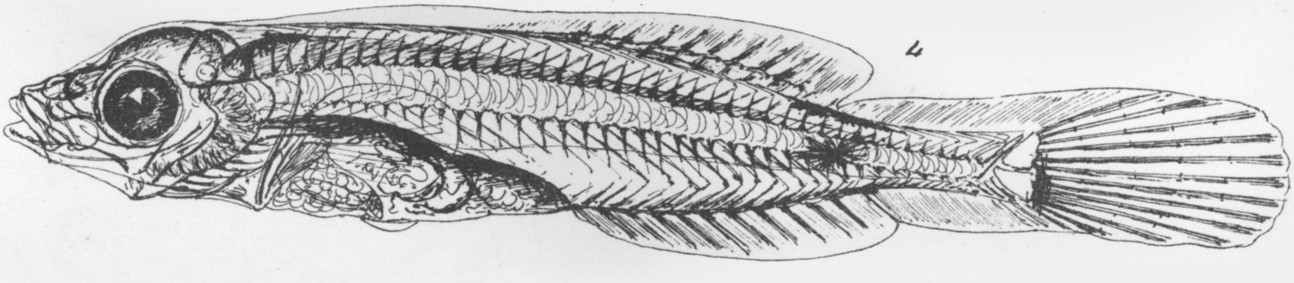

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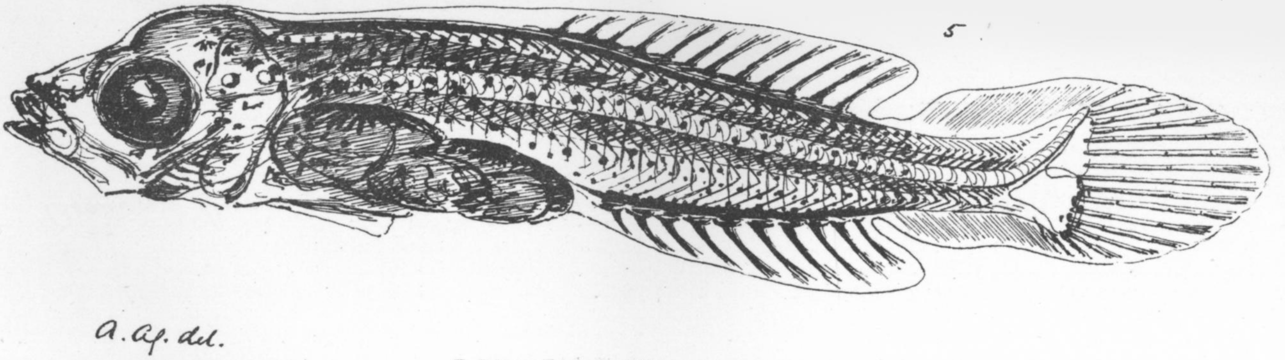

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Pl. XV

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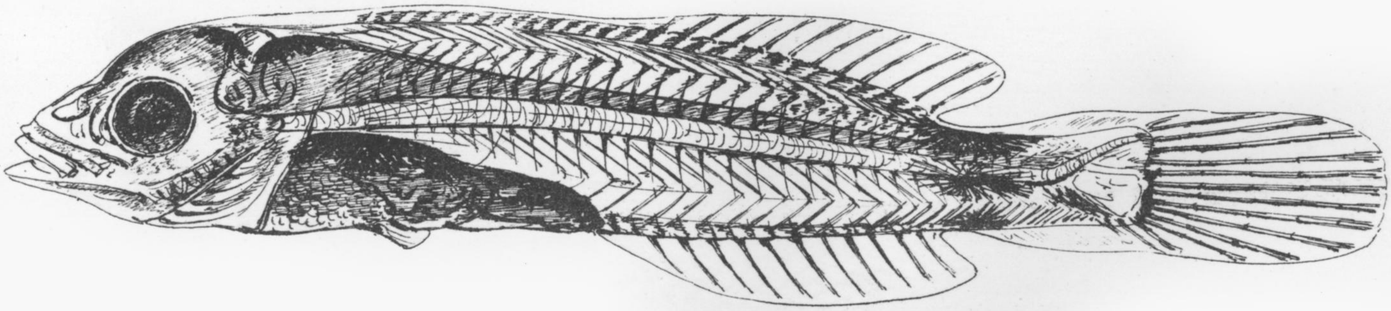

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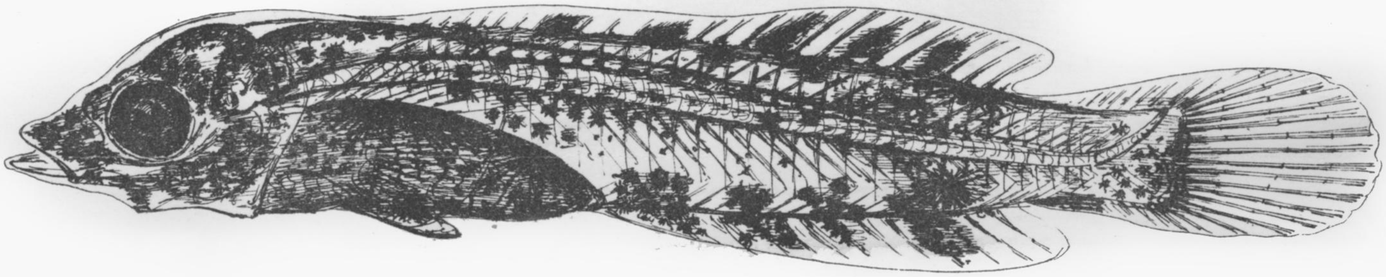

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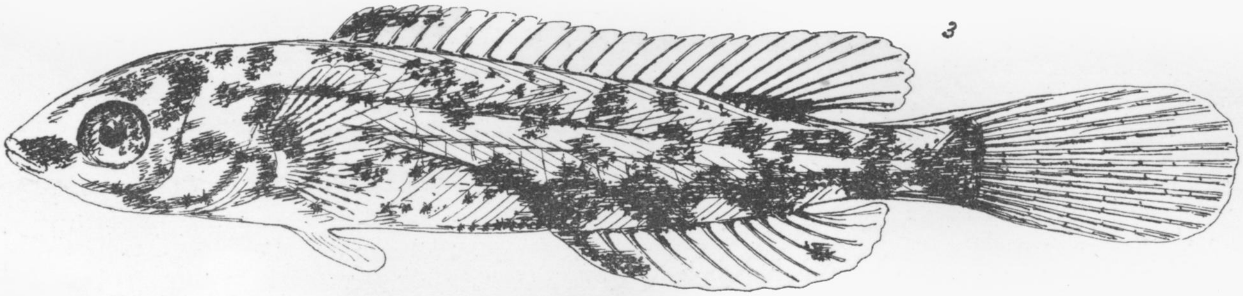

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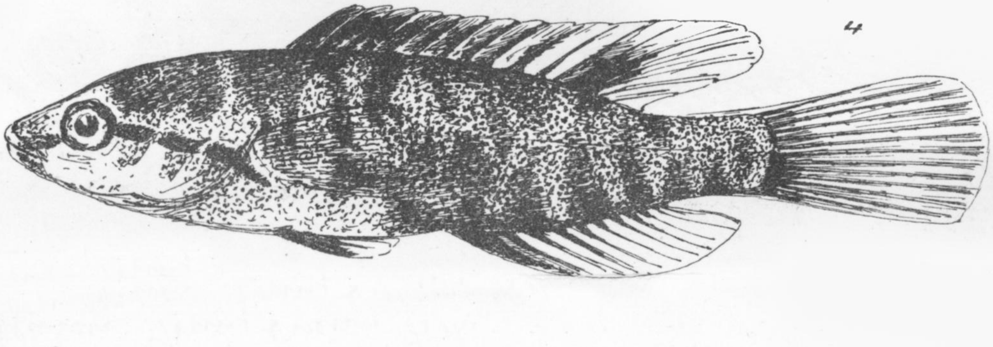

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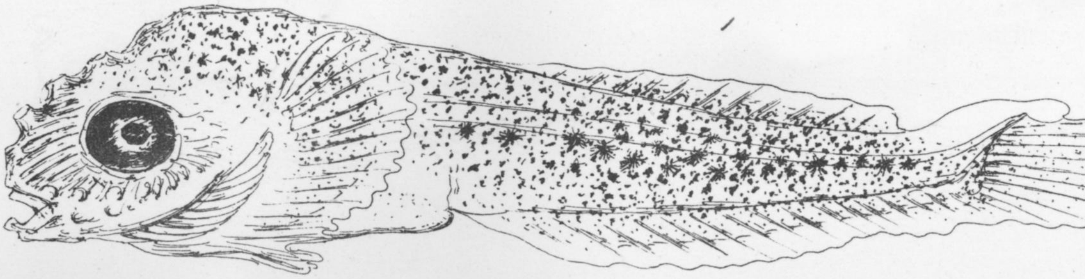
Pl. XVI



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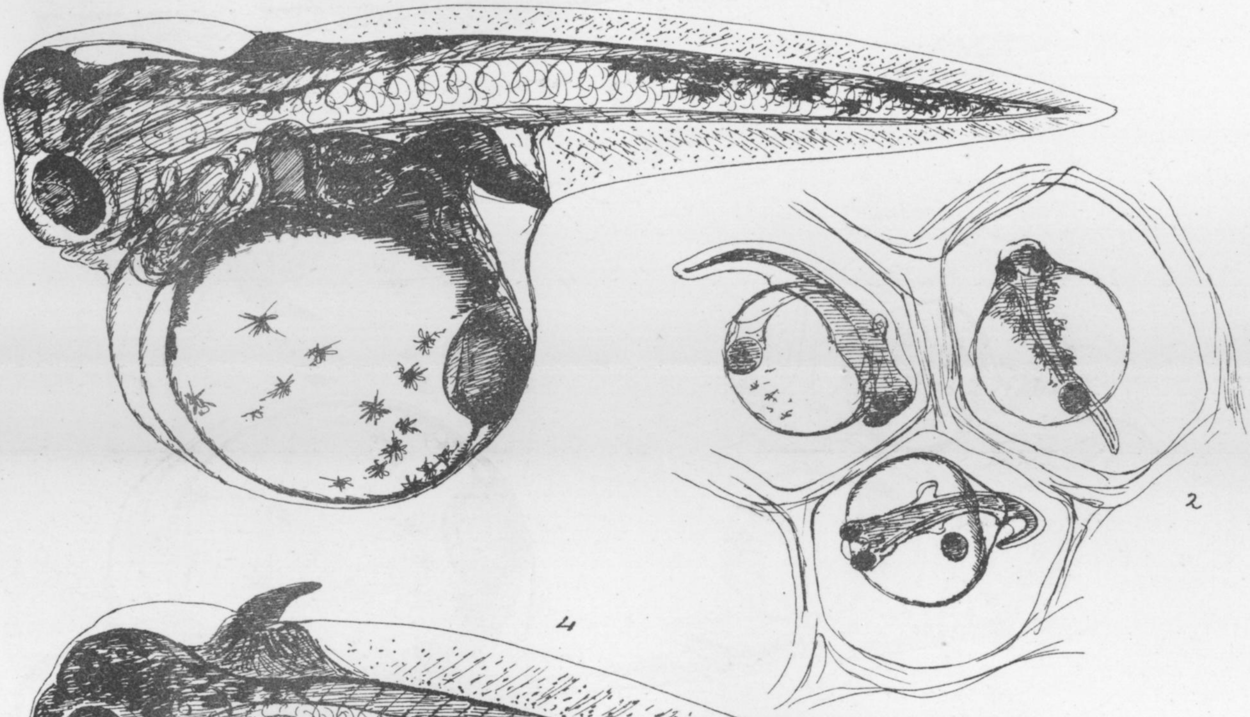

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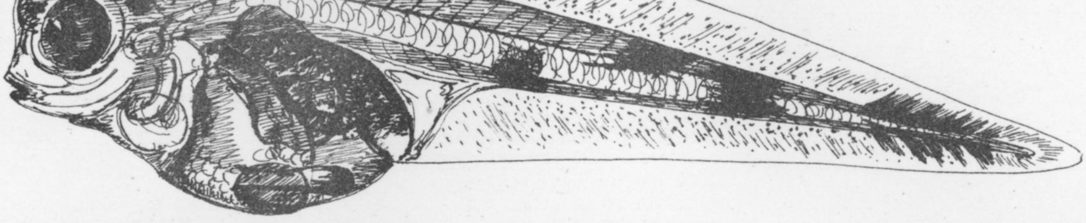

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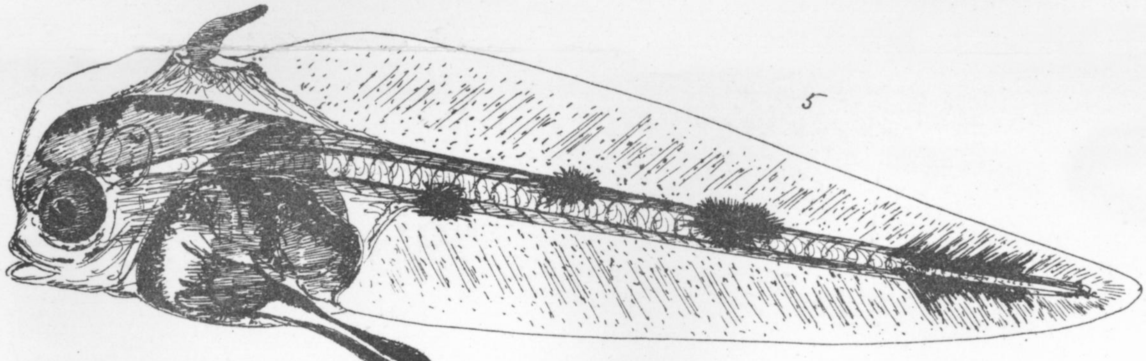

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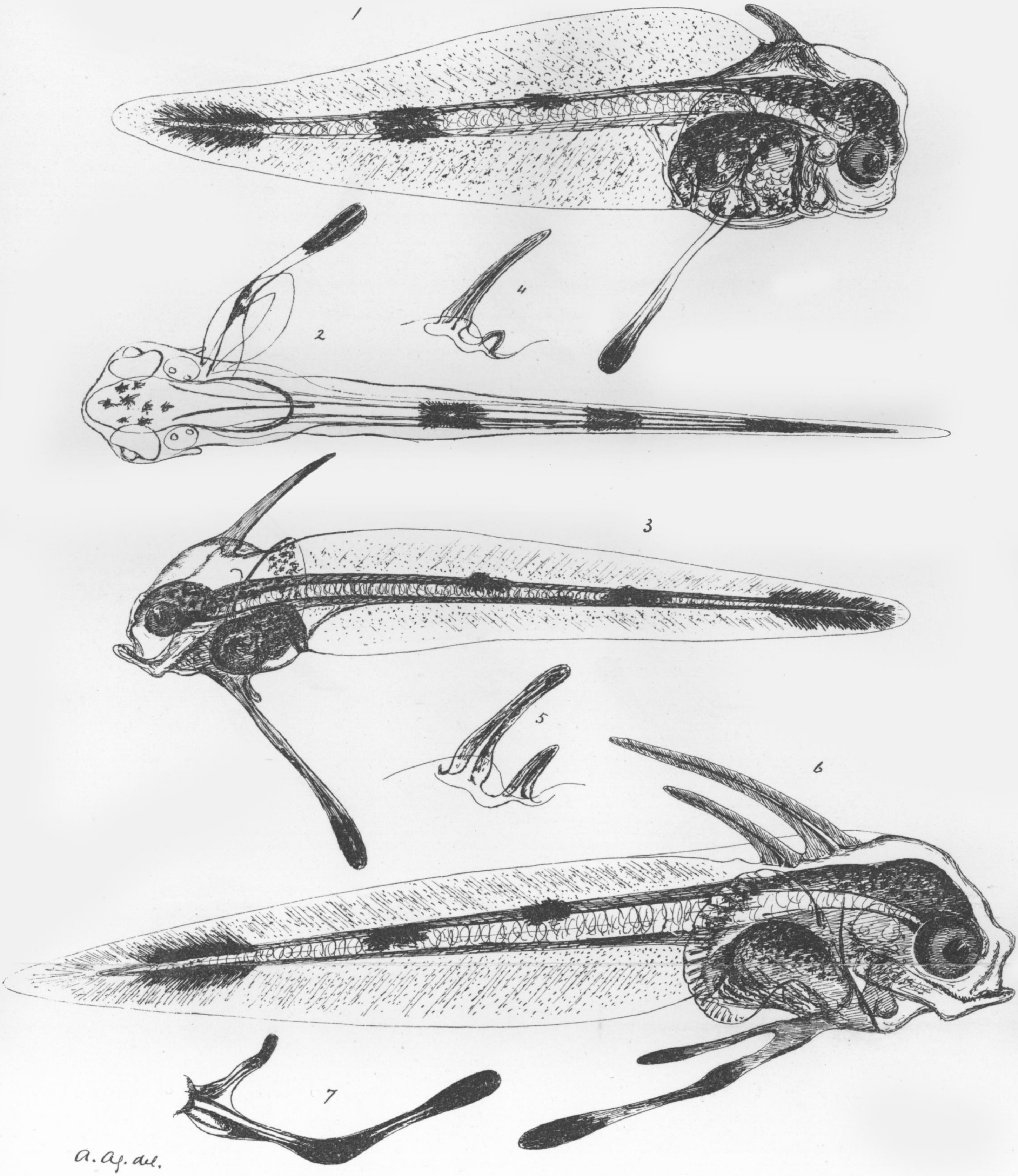
Pl. XVII



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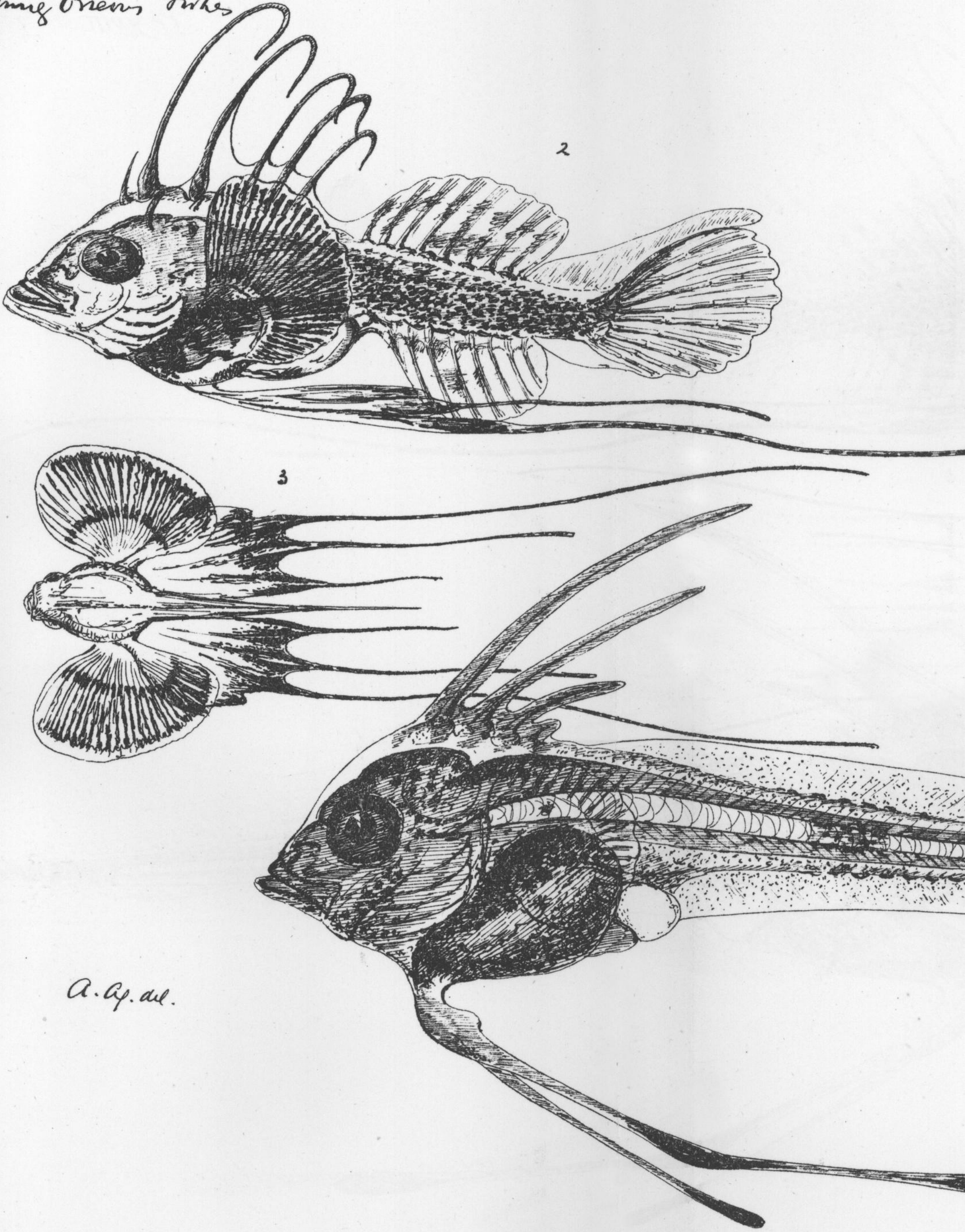

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Pl. XVIII

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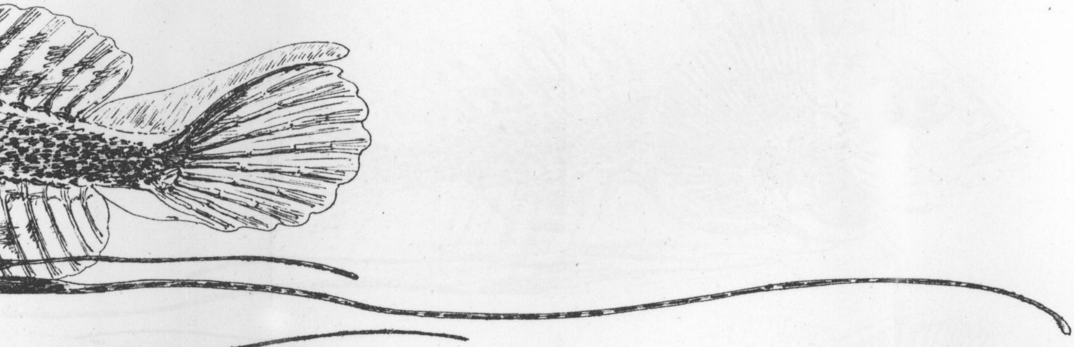

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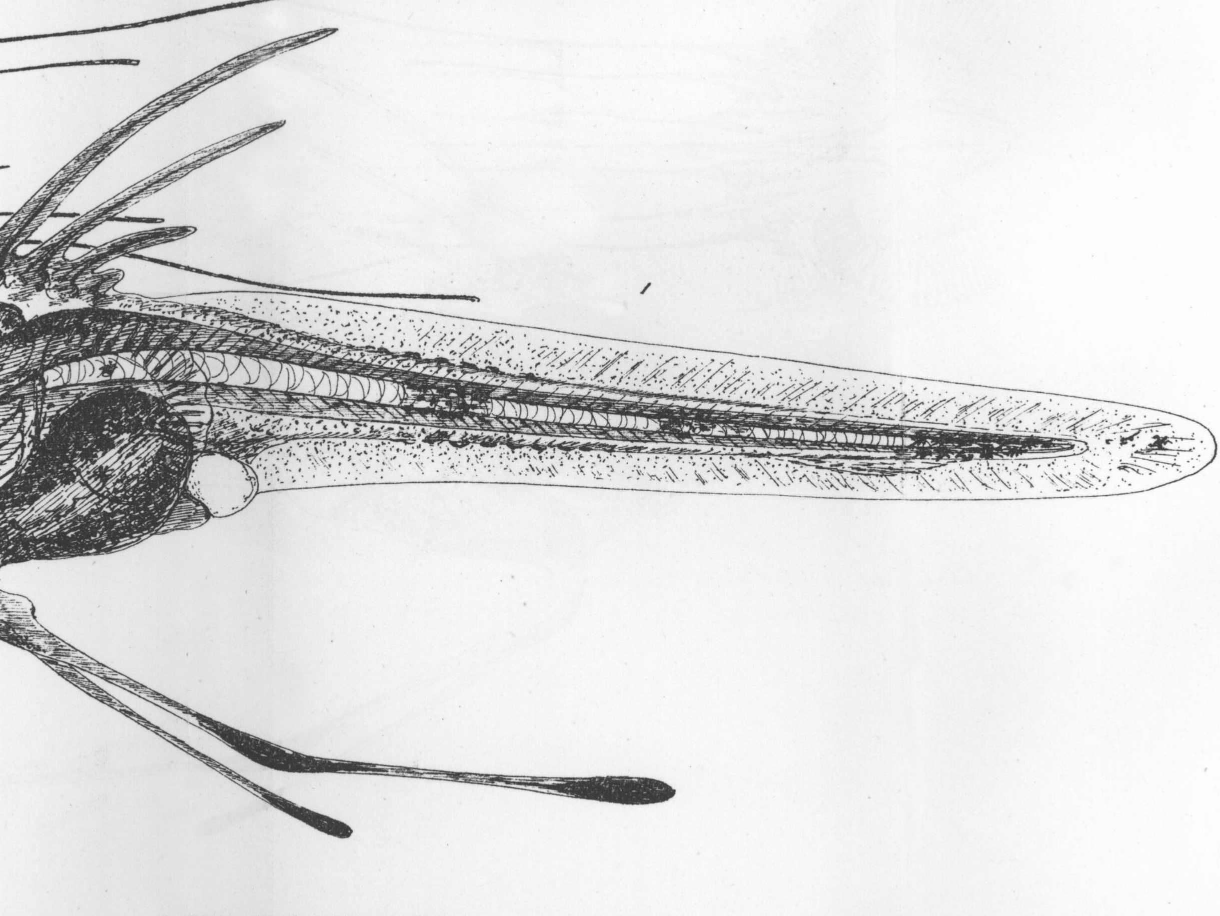

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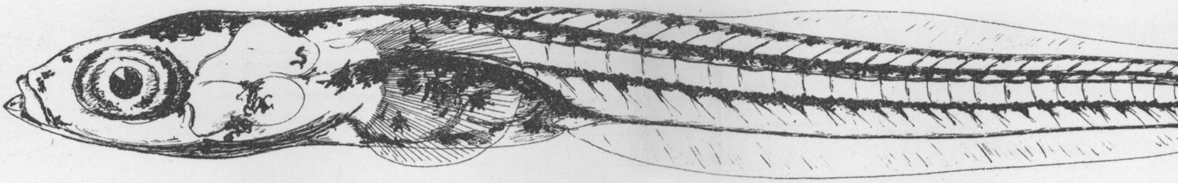

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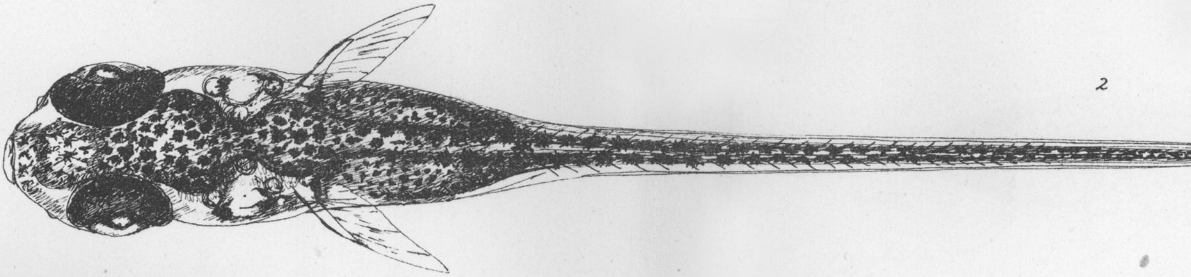

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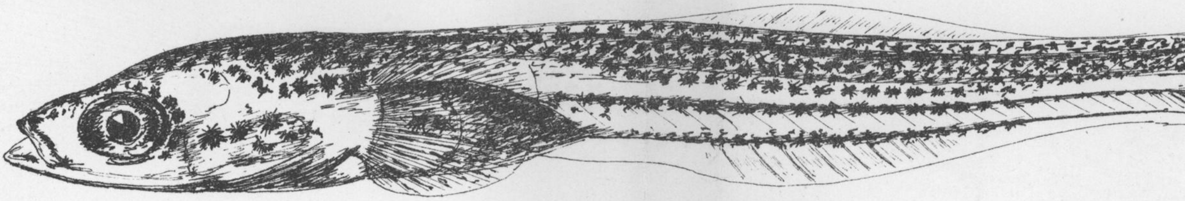

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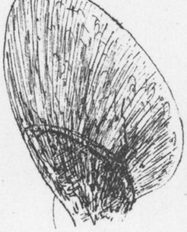

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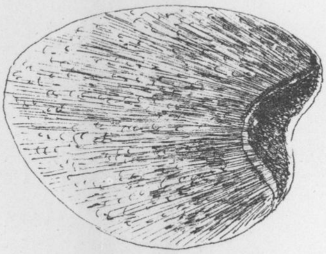

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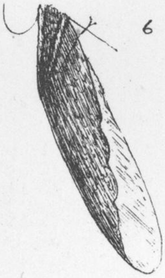

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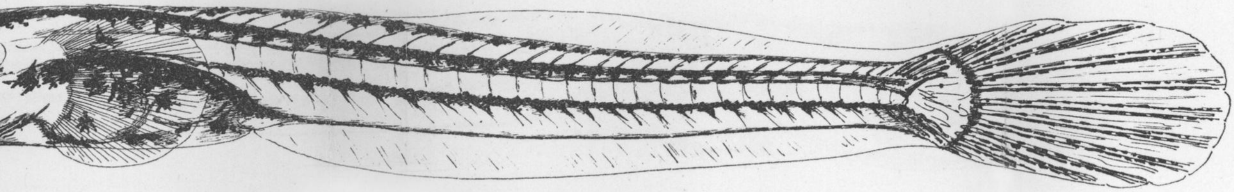

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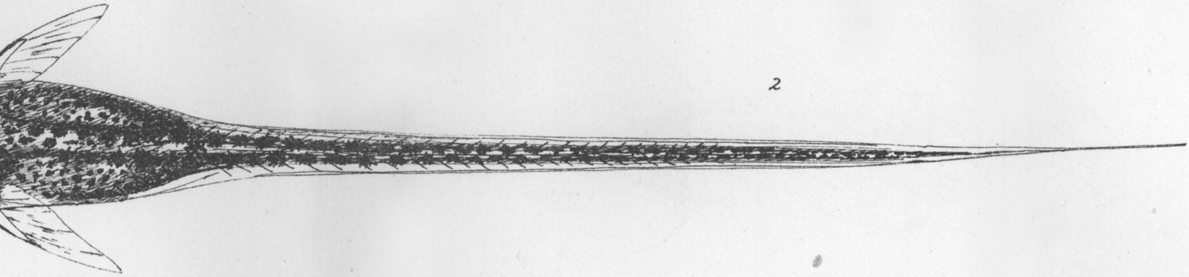

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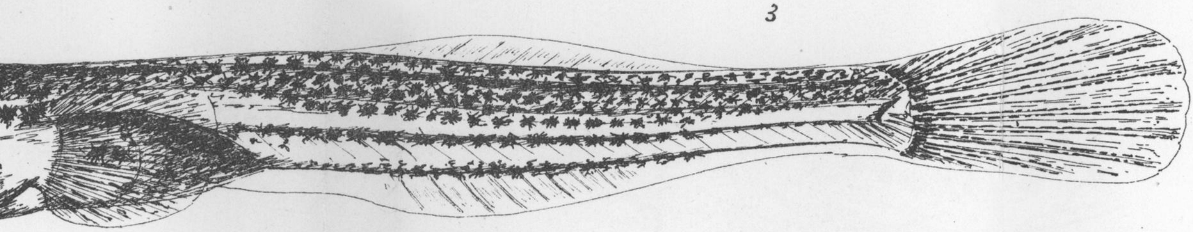

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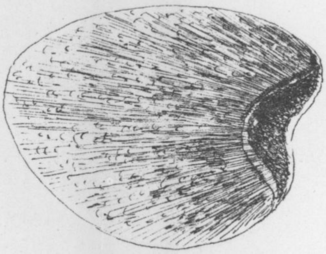

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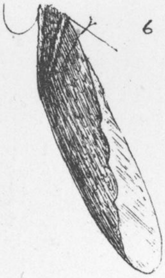

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Pl. XX

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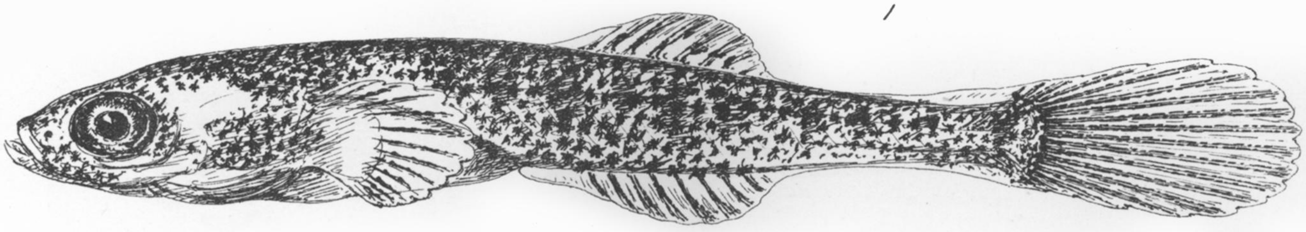

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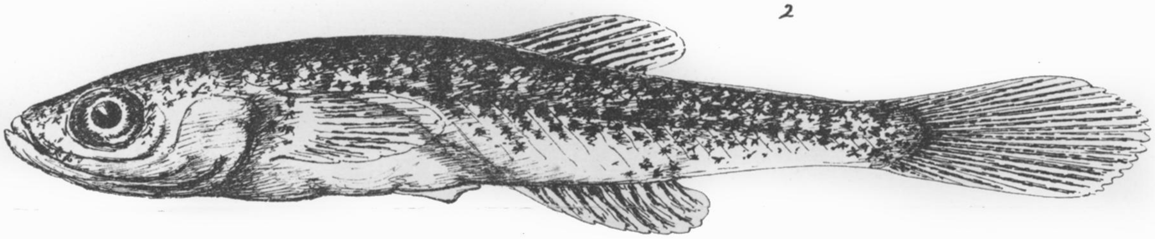

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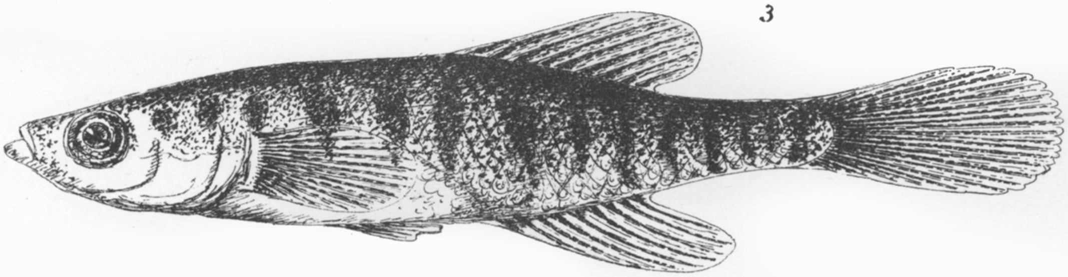

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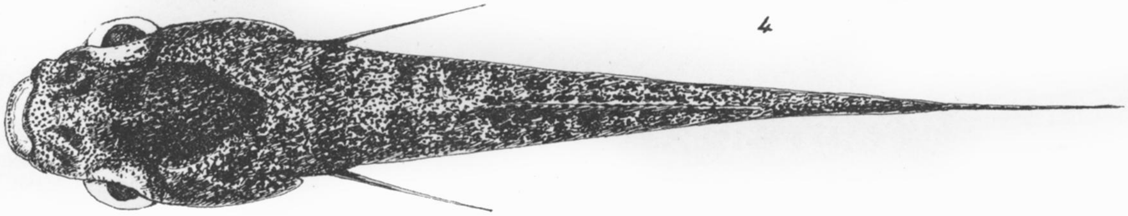

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# EXPLANATION OF THE PLATES.

## PLATE I.

### LABRAX LINEATUS, *Bl. & Sch.* (ROCCUS, *Gill.*)

Fig. 1. Young Labrax measuring 3.5$^{mm}$ in length.
" 2. Slightly older than fig. 1, measuring 4$^{mm}$ in length.
" 3. Still more advanced, measuring nearly 5$^{mm}$ in length.
" 3*a*. Tail of young Labrax somewhat older than stage of fig. 3, with a dorsal line of pigment spots.
" 4. Young Labrax in which caudal is forming, 8$^{mm}$ in length.
" 5. Somewhat more advanced than fig. 4.

## PLATE II.

Fig. 1. Young COTTUS GRŒNLANDICUS, somewhat older than stage of Plate III. fig. 5, measuring 8$^{mm}$ in length.
" 2. Profile view of young Cottus measuring 11.5$^{mm}$ in length.
" 3. Young Labrax 16$^{mm}$ in length.
" 4. Young Labrax 26$^{mm}$ in length.
" 5. Young Blue Fish (TEMNODON SALTATOR) measuring 9$^{mm}$ in length.

## PLATE III.

### COTTUS GRŒNLANDICUS, *C. & V.*

Fig. 1. Egg of Cottus found floating on the surface.
" 1*a*. First trace of pectorals of young Cottus still within the egg.
" 1*b*. Somewhat older stage of lateral fold.
" 1*c*. Still older stage than fig. 1 *b*, still within the egg.
" 2. Young Cottus just hatched, measuring 2.5$^{mm}$ in length.
" 3. Slightly older specimen, third day after hatching, seen from above.
" 4. Young Cottus, somewhat older than preceding stage, measuring 3$^{mm}$ in length.
" 5. Young Cottus eleventh day after hatching.

## PLATE IV.

### CYCLOPTERUS LUMPUS, *Lin.*

Fig. 1. Young Lumpus, seen in profile, measuring 4$^{mm}$ in length.
" 2. Same seen from above.
" 3. Young Lumpus, somewhat older than preceding stage, seen in profile.
" 4. Profile view of young Lumpus measuring 5$^{mm}$ in length.
" 5. Profile of young Lumpus measuring 10$^{mm}$ in length.

## PLATE V.

### CYCLOPTERUS LUMPUS, *Lin.*

Fig. 1. Young Lumpus $20^{mm}$ in length.
" 2. The same as fig. 1, seen from above.
" 3. Profile of young Lumpus still older, measuring $34^{mm}$ in length.
" 3*a*. Spiny protuberances along anterior dorsal line of anterior dorsal.
" 3*b*. Largest spiny protuberances of lateral line.
" 3*c*. Pectorals and ventrals seen from the abdominal side.
" 4. Same as fig. 3, seen from above.

## PLATE VI.

### PORONOTUS TRIACANTHUS, *Gill.*

Fig. 1. Young Butterfish $7^{mm}$ in length.
" 2. Somewhat older stage than fig. 1.
" 3. Older stage than fig. 2; $9^{mm}$ in length.
" 4. Slightly more advanced than fig. 3; $10^{mm}$ in length.
" 5. Young Butterfish having principal characters of the adult, $16^{mm}$ in length.

## PLATE VII.

### MOTELLA ARGENTEA, *Rhein.*

Fig. 1. Young, measuring $4^{mm}$ in length.
" 2. Somewhat older than fig. 1, $5^{mm}$ in length, seen in profile.
" 3. Same as fig. 2, seen from below to show rays of ventrals.
" 4. Young, measuring $7.5^{mm}$ in length.
" 5. Young, measuring $12^{mm}$ in length.
" 6. Slightly older than fig. 5, measuring $14.5^{mm}$ in length, seen in profile.

## PLATE VIII.

### MOTELLA ARGENTEA, *Rhein.*

Fig. 1. View from above of same embryo as Plate VII. fig. 6.
" 1*a*. Same as fig. 1, seen from above, with its ventrals fully expanded and spread out.
" 2. Young Motella with small anterior dorsal, measuring $15^{mm}$ in length.
" 3. Considerably older than fig. 2, measuring $34^{mm}$ in length.
" 4. Young Gadus measuring $25^{mm}$ in length.
" 5. Young Cod measuring $28^{mm}$ in length.

## PLATE IX.

### GASTEROSTEUS ACULEATUS, *Lin.*

Fig. 1. Young Gasterosteus with prominent ganoid tail fin measuring $7^{mm}$ in length.
" 2. Older stage, $12^{mm}$ in length, in which the embryonic fin lobe has disappeared, the tail fin has become symmetrical, and the permanent rays of the dorsal and anal are well developed.

Fig. 3. Slightly older than preceding stage. Rudiments of anterior dorsal spines and of ventrals have made their appearance, $15^{mm}$ in length.
" 4. In this stage the rudimentary anterior dorsal spines, as well as ventrals, have increased somewhat in length, the dorsal and anal are both higher, and the chromatophores of the body are arranged in bands somewhat as in the adult, $22^{mm}$ in length.
" 5. Young Gasterosteus, in which the principal characteristics of the adult are fairly developed, $27^{mm}$ in length.
" *5a*. Anterior spine of ventral of young Gasterosteus, somewhat older than preceding stage.

## PLATE X.

### ATHERINICHTHYS NOTATA, *Günth.* (CHIROSTOMA, *Gill*).

Fig. 1. Young Atherina measuring $5^{mm}$ in length.
" 2. Somewhat older stage, measuring $6.5^{mm}$ in length, seen from above.
" 3. About in stage of fig. 2, seen in profile.
" 4. Older than preceding stage, $9^{mm}$ in length.

## PLATE XI.

### ATHERINICHTHYS NOTATA, *Günth.*

Fig. 1. Somewhat more advanced than preceding stage (Plate X. fig. 4) $10,5^{mm}$ in length.
" 2. Young Atherina measuring $16^{mm}$ in length.
" 3. Young Atherina, having the principal characters of the adult, of about the same length as fig. 2.

## PLATE XII.

### OSMERUS MORDAX, *Gill.*

Fig. 1. Young Osmerus just hatched, measuring $5^{mm}$ in length, seen in profile.
" 2. Same seen from above.
" 3. Young Osmerus measuring $9^{mm}$ in length.
" 4. Considerably older than fig. 3; $22^{mm}$ in length.
" 5. Oldest Osmerus found swimming on the surface, measuring $22^{mm}$ in length.

## PLATE XIII.

### CTENOLABRUS CŒRULEUS, *Dek.*

Fig. 1. Young just hatched from the egg, $2^{mm}$ in length.
" 2. Young, on the second day after hatching, $3^{mm}$ in length.
" 3. Young on the third day after hatching.
" 4. Young on the third day after hatching, somewhat older.
" 5. Young hatched four days, about $4^{mm}$ in length, seen in profile.
" 6. Young same as fig. 5, seen from above.

## PLATE XIV.

### CTENOLABRUS CŒRULEUS, *Dek.*

Fig. 1. Young $5^{mm}$ in length, fished up at the surface. Caudal fin forming.
" 2. Young $6^{mm}$ in length, anal and dorsal fins separated from the caudal, ventrals commencing to form.
" 3. Young $6.5^{mm}$ in length, somewhat more advanced than fig. 2.
" 4. Young measuring $7^{mm}$ in length, the dorsal and ventrals somewhat better separated from the caudal fin than in the preceding stage.
" 5. Young $10^{mm}$ in length.

## PLATE XV.

### CTENOLABRUS CŒRULEUS, *Dek.*

Fig. 1. Young somewhat more advanced than the stage of Plate XIV., fig. 5, of about the same length.
" 2. Young $11^{mm}$ in length.
" 3. Young $15^{mm}$ in length.
" 4. Young of same size as preceding figure, but somewhat more advanced.

## PLATE XVI.

Fig. 1. Young BATRACHUS TAU, measuring $8^{mm}$ in length.

### LOPHIUS PISCATORIUS, *Lin.*

Fig. 2. Three eggs embedded in the gelatinous membrane in which they are laid; magnified.
" 3. Young Lophius taken out of the egg just previous to hatching.
" 4. Young Lophius just after hatching.
" 5. Somewhat older stage; the yolk bag has entirely disappeared.

## PLATE XVII.

### LOPHIUS PISCATORIUS, *Lin.*

Fig. 1. Slightly older stage than fig. 5, Plate XVI.
" 2. Same as fig. 1, seen from above.
" 3. Older than fig. 1; the second ray of ventrals commences to form.
" 4. Anterior dorsal of slightly older stage, showing the beginning of the second ray.
" 5. Anterior dorsal rays of specimen somewhat older than fig. 4.
" 6. Older stage than fig. 5, with longer dorsal rays in anterior fin and rudiment of third; two large ventral rays.
" 7. Ventral rays of specimen somewhat older than fig. 3, about in the stage of fig. 5.

## PLATE XVIII.

### LOPHIUS PISCATORIUS, *Lin.*

Fig. 1. Young Lophius showing still greater increase in length and number of anterior dorsal and ventral rays.
" 2. Oldest pelagic stage, measuring $30^{mm}$ in length, seen in profile.
" 3. Same seen from above, slightly less magnified.

## PLATE XIX.

### FUNDULUS NIGROFASCIATUS, *C. & V.*

Fig. 1. Young, measuring $7^{mm}$ in length.
" 2. Same seen from above.
" 3. Older than fig. 1; dendritic pigment cells more numerous in the upper part of the head; the nearly unbroken lines of chromatophores are broken up into separate cells; the permanent rays of the dorsal and anal fins make their appearance.
" 4. Crossopterygian stage of pectoral of young Fundulus about in stage of fig. 1, from the side.
" 5. Same fin seen from above, slightly bent laterally when in motion.
" 6. Same fin seen from above, at rest.

## PLATE XX.

### FUNDULUS NIGROFASCIATUS, *C. & V.*

Fig. 1. Young measuring $11^{mm}$ in length and uniformly covered with dendritic chromatophores, dorsal and anal quite high, well separated from the caudal; first trace of ventrals.
" 2. Young measuring $16^{mm}$ in length, body more compact, ventrals quite distinct, anal and dorsal slightly lobed, caudal rounded, pectoral elongated, whole body covered uniformly by closely packed dendritic chromatophores.
" 3. Young measuring $20^{mm}$ in length; although the head is still comparatively larger than in fig. 4, yet the anterior part of fish has assumed the characteristic sloping outline of the adult. The scales are already well developed in this stage. The pigment cells are comparatively smaller than in younger stages, and very closely packed over the whole surface, especially on the dorsal side.
" 4. Same as fig. 3, seen from above.